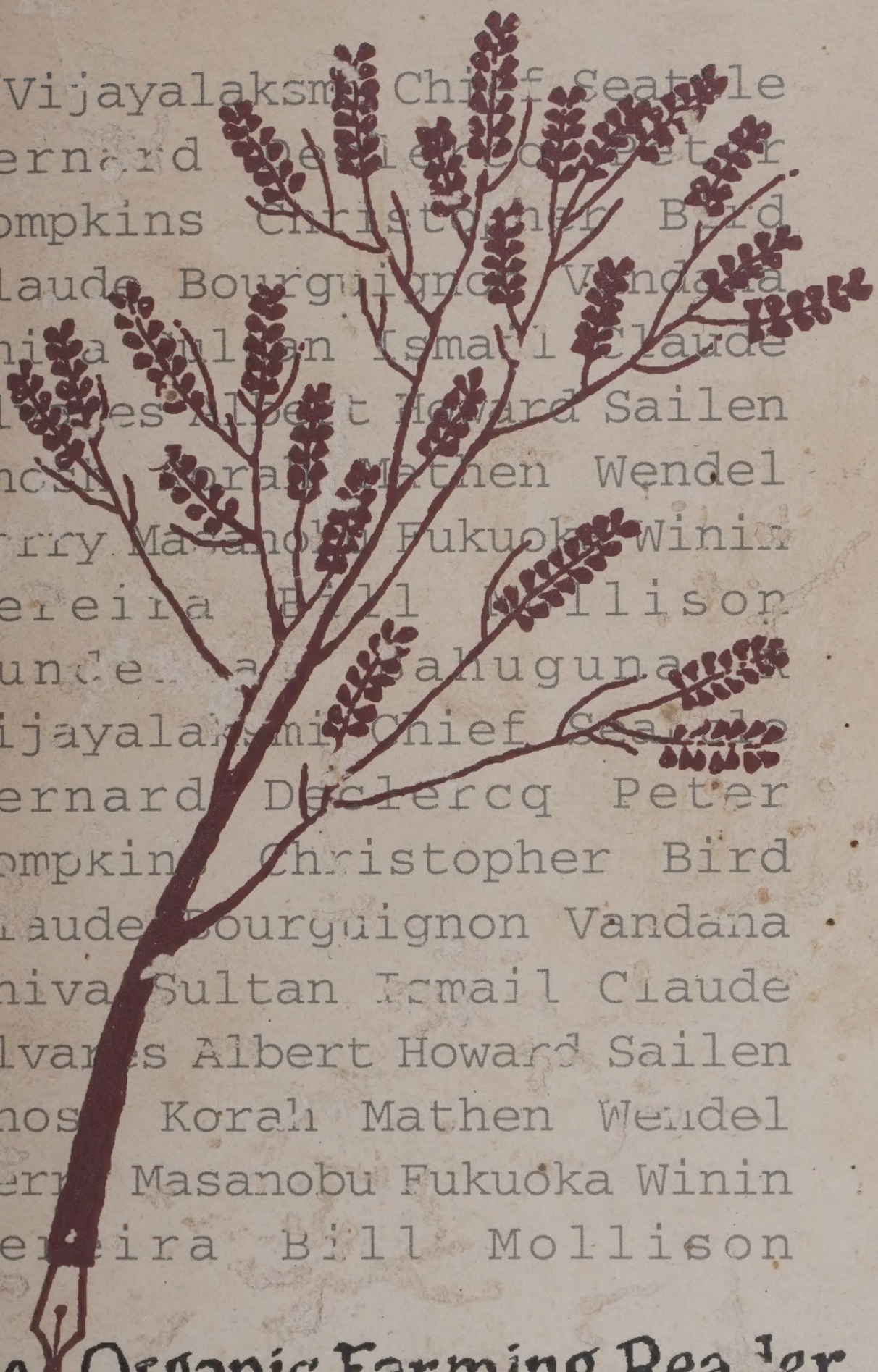

The Organic Farming Reader

Edited by • Claude Alvares • Vandana Shiva
Sultan Ismail • K Vijayalakshmi • Korah Mathen • Bernard Declercq

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in association with

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Korah Mathen has worked for several years with the Lalbhai Group in Ahmedabad where he has continued to run the Group's rural development service. He is also the secretary of the Association for the Propagation of Indigenous Genetic Resources set up in 1984.

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Section I

The Philosophy and Ethics of Organic Farming

Section editor: Claude Alvares

There are several competing philosophies today that underwrite one or another form of agricultural practice.

The educated, literate world largely recognises or knows only the modern method of farming involving the use of tractors, harvesters, chemical fertilisers and pesticides. This is also the dominant system since it is actually linked with a particular system of commerce. The driving philosophy behind the global extension of this form of agriculture is the objective of money profits. The state in every country supports this form of agriculture with an unimaginable quantity of subsidies. Despite the fact that such agriculture would not be able to survive without such subsidies, it is still widely propagated as the more efficient form of growing food. Strange?

It is not our intention therefore to provide in this *Reader* information regarding the modern method of farming since every printed text book available and every agricultural university and extension system in India or elsewhere teaches farming based on heavy equipment, high external inputs, high energy inputs, marketed seeds and so on. There is in fact a surfeit of information available in print and other media forms on modern agriculture. We do not need to grant it additional space in these pages too. Should the student wish to access more information on the modern way of farming, s/he is welcome to browse through the pages of the *Organic Farming Source Book* which critically documents the principal history and the main features of such agriculture.

As the title announces, this is a *Reader* devoted exclusively to material required for the study of alternative agriculture. We use the label 'alternative' to distinguish it from conventional farming described briefly above. But included in the label are more than a dozen forms of agriculture including traditional subsistence farming, organic agriculture, permaculture, natural farming and others, all

using methods that may not be as influential as conventional doctrines in farming but still pervasive in many regions of the world. Modern organic farming, for instance, is steadily gaining ground year by year not only in terms of acreage, but in terms of market share. As the consumers of the global market get increasingly wary about the products of conventional agriculture, the latter's deficient nutritional quality, the indiscriminate use of genetically engineered materials, the frightful cost in terms of environmental damage to the soil and to biodiversity and the association of this form of agriculture with more and more lethal toxins, they are bound to patronise farmers who have shifted to alternative agriculture. As for farmers, they will find in such agriculture not only a more sustainable method of raising crops, but a richer philosophy of life as well.

Readers are designed to provide a general overview and feel for the subject they wish to introduce. They are designed not only for the already initiated but for those entering the subject for the first time as well. Each essay presented must be complete in itself and it must tell a story or make an argument or a point that is convincing to the person reading it.

There are ten essays, some short, some long, in this section on the philosophy and ethics of organic farming.

The first essay is a rather well known statement by an American Indian chief writing to a US President who wished to buy lands owned by the native American community. The statement has been included in this selection because—though widely circulated—it remains a classic declaration of the relationship of people to land outside the cultural framework of Europe. The statement contains a profound declaration of non-Western attitudes to the soil, the land and the animals that sustain themselves on the resources of the earth. It also reflects the dismay most people feel at the wanton destruction of natural capital that we have come to associate with the profligate, plundering, capitalist West.

Some researchers claim the statement is apocryphal. Whether that claim is true or not, whether Chief Seattle existed or not, is irrelevant in our case as the intention of this selection here is to teach, to open the windows of the mind, and to invite the reader to sample a range of rich, diverse, unconventional perspectives. Chief Seattle's declaration, for example, is not alien to Indian cultural traditions. In India all land has always been traditionally considered God's land and ownership of land as we know it today—inherited from English law—was non-existent. The historian Dharampal has in fact shown that in the *samudayam* villages of South India agricultural lands were occasionally pooled together and redistributed by lots to prevent the most fertile lands being in the exclusive possession of just one or two families.

Modern agriculture with its approach to land as a factor of production suppresses this perspective entirely. The modern view is to treat everything as a commodity. It is not that this view, though dominant, has received general acceptance. Many across the planet, even in the West itself, find it offensive and unacceptable. Those who treat the land with reverence—as our traditions urged us to do earlier—are habituated to see it in terms of a gift given to them to be used wisely so that all creatures and sentient beings, including the earthworm and the bird can continue to have claim on it, live on it and survive.

The essay that follows Chief Seattle's, 'Food Farmers and Dollar Farmers', is taken from the *Challenge of the Primitives* and is included in this selection because it is an admirable description and defence of slash-and-burn agriculture—also known as swidden agriculture. (In our own Konkan area, it is labelled *kumeri*).

The authors demonstrate that swidden is a form of extremely efficient agriculture which returns the land after cultivation to its natural state. This can be contrasted with the consequences associated with the practices of modern agriculture which generally turn the land—after use—into an unnatural state, a state in which it does not exist as such in nature, barren of soil microbes, earthworms and birds.

Also in swidden agriculture, the land is treated as a common resource and not as private property, which is perhaps the primary reason why it remains unattractive to the modern economic system based on private ownership.

The third essay is by Wendel Berry, one of the finest writers available today on agriculture, especially the destruction of American agriculture. In the essay, Berry deals with three types of traditional agriculture: the agriculture of the Andes; the traditional agricultures still surviving in the United States and the farming system of the Amish communities of which there is a considerable literature available. The three extracts taken together provide a remarkable defence of forms of agriculture that refuse to consider as essential many of the tools of modern agriculture, including synthetic fertilisers, pesticides and tractors.

The fourth extract—taken from *The Secret Life of Plants*—has been included because it provides a remarkable perspective of plants as sentient organisms. Plants do have feelings. Through our educational system, we have often been brought up to believe that human beings are the most sentient of living creatures, with the animals and plants in a descending scale in terms of feelings. *The Secret Life of Plants* has succeeded in thoroughly undermining this hierarchy of feeling arbitrarily established by man. Though the

farmer is still advised to read the entire book if s/he can get a copy, the present extract should give her or him a fairly good idea of the subject. At least it will prevent him/her from dousing and killing plants with deadly chemicals.

The essay that follows by Sir Albert Howard is taken from his classic, *An Agricultural Testament*. It is included in this selection because Albert Howard felt that our agriculture will be successful, sustainable and permanent only in so far as we are able to imitate the natural procedures of forest systems.

Sir Howard drew attention to the fact that forest systems create their own manures, control disease, maintain soils, harbour millions of living communities and still produce large quantities of biomass far more successfully than human beings equipped with the entire paraphernalia of modern farming.

Masanobu Fukuoka does not need any introduction as he is well known all over the globe as the inventor of natural farming. The reader is advised to read carefully all the three books available in English by this Japanese writer and farmer. The present extracts have been selected primarily to focus on the main principles of natural farming as propounded by Fukuoka himself and they are taken largely from *The Natural Way of Farming*.

The following selection is taken from the writings of Sailen Ghosh. Ghosh, now eminently grey and residing in Delhi, has been writing on sustainable agriculture for the last 30 years. He is a thorough writer and labours hard to see that no questions or doubts are left in the reader's mind after s/he has completed studying his arguments concerning why organic farming is necessary for the agriculture of the future. Though Ghosh has written several articles, he has yet to produce a book.

The following piece by Tompkins and Bird relates the experiments associated with the Findhorn Garden experiment in the United Kingdom. Findhorn was started by a group of spiritually inclined people who set up a productive agricultural garden in consultation with *devas*. They eventually documented their experiments in a beautiful book. Since the book is not easily available, we have decided to include the essay on Findhorn by Tompkins and Bird instead.

The final piece in the selection is taken from Bill Mollison's large volume, *Permaculture*. An Australian farmer, Mollison has moved around the world propagating a designer form of agriculture which mimics ecology and respects the general principles of organic farming. We have included a critical piece on permaculture by Winin Pereira (author of two well known books, *Asking the Earth* and *Tending the Earth),* which brings this selection to a fine controversial end.

We are part of the Earth

By Chief Seattle

Whatever befalls the Earth befalls the Sons of the Earth.

How can you buy or sell the sky, the warmth of the land?

The idea is strange to us.

If we do not own the freshness of the air and the sparkle of the water, how can you buy them?

Every pine needle, every sandy shore, every mist in the dark woods, every clearing and humming insect is holy in the memory and experience of my people. The sap which courses through the trees carries the memories of the red man.

The white man's dead forget the country of their birth when they go to walk among the stars. Our dead never forget this beautiful earth, for it is the mother of the red man. We are part of the earth and it is part of us. The perfumed flowers are our sisters; the deer, the horse, the great eagle, these are our brothers. The rocky crests, the juices in the meadows, the body heat of the pony, and man - all belong to the same family.

So, when the Great Chief in Washington sends words that he wishes to buy our land, he asks much of us. The Great Chief sends word he will reserve us a place so that we can live comfortably to ourselves. He will be our father and we will be his children. So we will consider your offer to buy our land. But it will not be easy. For this land is sacred to us.

This shining water that moves in the streams and rivers is not just water but the blood of our ancestors. If we sell you land, you must remember that it is sacred, and you must teach your children that it is sacred and that each ghostly reflection in the clear water of the lakes tells of events and memories in the life of my people. The water's murmur is the voice of my father's father.

The rivers are our brothers, they quench our thirst. The rivers carry our canoes, and feed our children. If we sell you our land, you must remember, and teach your children that the rivers are our brothers, and yours, and you must henceforth give the rivers the kindness you would give any brother.

We know that the white man does not understand our ways. One portion of land is the same to him as the next, for he is a stranger who comes in the night and takes from the land whatever he needs. The earth is not his brother, but his enemy and when he has conquered it, he moves on. He leaves his father's graves behind, and he does not care.

He kidnaps the earth from his children. His father's grave, and his children's birthright are forgotten. He treats his mother the earth and his brother, the sky, as things to be bought, plundered, sold like sheep or bright beads. His appetite will devour the earth and leave behind only a desert.

I do not know. Our ways are different from your ways. The sight of your cities pains the eyes of the red man. But perhaps it is because the red man is savage and does not understand.

There is no quiet place in the white man's cities. No place to hear the unfurling of leaves in spring, or the rustle of an insect's wings. But perhaps it is because I am a savage and do not understand. The clatter only seems to insult the ears. And what is there to life if a man cannot hear the lonely cry of the whippoorwill or the arguments of the frogs around a pond at night? I am a red man and do not understand. The Indian prefers the soft sound of the wind itself, cleansed by a mid-day rain, or scented with the pinon pine.

The air is precious to the red man, for all things share the same breath—the beast, the tree, the man, they all share the same breath. The white man does not seem to notice the air he breathes. Like a man dying for many days, he is numb to the stench. But if we sell you our land, you must remember the air is precious to us, that the air shares its spirits with all the life it supports. The wind that gave our grandfather his first breath also receives his last sigh. And if we sell you our land, you must keep it apart and sacred, as a place where even the white man can go to taste the wind that is sweetened by the meadow's flowers.

So we will consider your offer to buy our land. If we decide to accept, I will make one condition: The white man must treat the beasts of this land as his brothers.

I am a savage and I do not understand any other way. I have seen a thousand rotting buffaloes on the prairie, left by the white man who shot them from a passing train. I am a savage and I do not understand how the smoking iron horse can be more important than the buffalo that we kill only to stay alive.

What is the man without beasts? If all the beasts were gone, man would die from a great loneliness of spirit. For whatever happens, to the beasts, soon happens to man. All things are connected.

You must teach your children that the ground beneath their feet is the ashes of our grandfathers. So that they will respect the land; tell your children that the earth is rich with the lives of our kin. Teach your children what we have taught our children, that the earth is our mother.

Whatever befalls the earth befalls the sons of the earth. If men spit upon the ground, they spit upon themselves.

This we know: The earth does not belong to man, man belongs to the earth. All things are connected like the blood which unites one family. Man did not weave the web of life: He is merely a strand in it. Whatever he does to the web, he does to himself.

Even the white man, whose God walks and talks with him as friend to friend, cannot be exempt from the common destiny. We may be brothers after all. We shall see. One thing we know, which the white man may one day discover—our God is the same God. You may think that you own Him as you wish to own our land, but you cannot. He is the God of man, and his compassion is equal for the red man and the white. This earth is precious to Him, and to harm the earth is to heap contempt on creator. The white too shall pass, perhaps sooner than all other tribes. Contaminate your bed and you will one night suffocate in your own waste.

But in your perishing you will shine brightly, fired by the strength of the God who has brought you to this land and for some special purpose gave you dominion over this land and over the red man. That destiny is a mystery to us, for we do not understand when the wild buffalo are all slaughtered, the wild horses are tamed, the secret corners of the forest heavy with scent of many men and the view of the ripe hills blotted by talking wires. Where is the thicket? Gone. Where is the eagle? The end of living and the beginning of survival.

Food Farmers and Dollar Farmers

By Robin Clarke and Geoffrey Hindley

"Swithen" or "swivven" is an old northern English word meaning "to burn, sweal or singe, as heather". It is used now, in the form "swidden", to denote a kind of agriculture better known as "slash-and-burn" which was once practised from Scandinavia to Melanesia. In a primitive economy it is by far the most common form of agriculture. And as it differs so markedly from modern ideas of farming, it has for long been a target of special abuse for those concerned with agricultural development in the Third World.

Essentially, the technique is used in forest and scrubland. First, a small area is cleared with simple axes or machetes, the larger timber taken out for firewood or fencing, and the smaller brushwood laid out on the clearing and allowed to dry for perhaps a couple of months. Meanwhile the garden clearing is fenced and then the area

is ignited. Everything is burnt and the garden is then planted out, using the ash as fertilizer. Nothing is added except seed and labour and after a few months the first produce is collected. The garden is replanted as many times as useful food can be obtained from it—the first crop is usually good, the second much poorer and the third often negligible. After two or three years, then, the garden is abandoned and a new clearing is made. When the forest has regenerated, in as little as ten years in some tropical regions, the process may be repeated.

This practice has been an easy target for both anthropologists and Western agriculturalists. A vast literature exists explaining how this very primitive, simple and easy technique of food production must be stamped out, and stamped out quickly. The charges are that it wastes enormous volumes of timber; that most of the nutrients are lost into the air during burning; that it leads rapidly to soil erosion; that the fires often spread much wider than the original clearing, destroying vast tracts of otherwise exploitable forest; that the new forest which grows up is always different from the poorer than the original; that the technique can be used to support only very low population levels; that it can only be used by nomads, and thus prohibits the setting up of a centralized, urban society; that it does not make use of the principle of crop rotation; that the crops are of poor quality and, worse, that they have no commercial value. Further—and this to the Western eye may be the most heinous crime of all—such a system of agriculture cannot be relied upon to cultivate the concept of private property.

Pitting his modern mind against the problem of how to wrest maximum production from the land, civilized man, it is usually argued, has found the real solutions. First, small plots of workable land have been systematically replaced by vast prairie tracts of unbroken pasture and arable land. By using just one crop over areas of perhaps several hundreds acres, the work input to agriculture can be minimized and its mechanization and profitability maximized. With the help of the chemical industry and the tractor combines, productivity per acre has been raised and raised every year. New strains of high-yielding plants have been produced and have spread their net globally. By turning food production into an industry, massive world-wide famine has been avoided, it is claimed, and a system of agriculture instituted which will in time feed the four billions we will soon have on the Earth's surface. The land has been conquered, and if somewhat more than half the world population still feels (and knows) that it is hungry, then we have only to tighten our belts (or rather they have to tighten theirs) for a few more years until agro-business has taught even the most illiterate the proper way to grow their food and get rich at the same time.

To be sure, these stereotypes of swidden and modern farming have a certain basic relationship to reality. But stereotypes they certainly are. And in the past decade a new attempt has been made to re-examine the basis of swidden farming from a more ecological point of view. The result has been surprising, for many if not all the old critiques of the process have been judged either faulty or at best partially true.

One of the key points at issue is ecological stability. Today, it is widely accepted that the monoculture form of agriculture is perhaps the most profitable but the most ecologically unstable. This is basically because it turns land into an ecological system about as far removed from the natural one as can be imagined. Plants are not simple biological organisms which can be successfully grown simply with the right mix of chemicals and a suitable supporting medium. Each species depends for its health on the presence of other living organisms, plants and animals, both up and down the ecological ladder. A healthy ecosystem is one in which there is therefore great diversity and a steady-state situation between the individual species and the natural environment. Were it not for the chemicals and mechanical equipment now used in farming, our own monocultures would be perilously unstable, subject every year to one disease or predator which would always wipe them out—as indeed still happens with crops such as maize in the United States in spite of all our technical efforts. But a swidden garden is something quite different, as Harold C. Conklin has written:

"At the sides and against the swidden fences there is found an association dominated by low, climbing or sprawling legumes (asparagus beans, sieva beans, hyacinth beans, string beans and cowpeas). As one goes into the center of the swidden, one passes through as association dominated by ripening grain but also including numerous root crops, shrub legumes and tree crops. Pole-climbing yam vines, heart-shaped taro leaves, ground-hugging sweet potato vines, and shrub-like manioc stems are the only visible signs of the large store of starch staples which is building up underground, while the grain crops fruit a meter or so above the swidden floor before giving way to the more widely spaced but less rapidly maturing tree crops. Over the first two years a new swidden produces a steady stream of harvestable food in the form of seed grains, pulses, sturdy tubers, and underground stems, and bananas, from a meter below to more than 2 meters above the ground. And many other vegetable, spice and nonfood crops are grown simultaneously."

In other words diversity seems to be the key to swidden gardening, which attempts not only to mix different types of plant together but also to utilize their differing depths of growth from below to above ground level in a way which has also earned it the name "ver-

tical gardening". All this is evident in the swidden gardener's vocabulary and garden expertise. The Hanunoo of the Philippines, for instance, habitually grow at least forty-eight different species in one swidden which may be two or three acres big, and they recognize four hundred and thirty different kinds of cultivated plant. In the first year in a swidden they may plant up to one hundred and fifty specific crop types.

In this way, the most characteristic form of primitive agriculture seeks not to do away with nature but rather to adapt, to provide a harvest more utilizable by man than the natural one. It has been said that the swidden gardener turns the natural forest into a harvestable one, and in doing so of course he reaps the benefits that accrue from not disturbing nature too profoundly. Were he, for instance, to attempt to grow a single crop over large areas in a cleared tropical forest, experience has shown there is one inevitable result. First, the weeding problems quickly get out of hand in a hot and humid environment where growth can be extremely rapid—in the tropics a bamboo can grow as much as thirty inches in a single day. But more important than this, the poor tropical soil is quickly leached out by the burning sun and the heavy rain, leading to a process of soil erosion known as laterization. Laterized soils are often impossible to work and are to be found wherever the forest has been deprived of its natural cover. They are now a common feature in Vietnam where spraying with defoliants has wreaked an ecological damage which will last several decades at least.

The harvestable forest of a swidden garden avoids this effect, or keeps it to a minimum, and allows the soil quickly to regain its natural state when the swidden reverts to natural forest. And the fertilizer for the swidden itself is not so much extracted from the poor soil but from the ash formed when the clearing is burnt. In this way the natural process of growth and decay is merely accelerated in time, and not altered grossly in character. Proof of this comes from the observation that in areas where altitude prevents the burning of the garden because there is no dry period, rice production from a swidden is only one third to one half that of areas where burning can take place.

By retaining the natural parasol effect of the tropical forest, the swidden garden also helps cut down on weeding. Of course, a swidden garden does need weeding, perhaps two or three times completely, but the work is made much lighter by the presence of green matter between the garden soil and the sun itself. For this reason a large labour force is not required and on average the swidden requires the adult members who depend on it to work between five hundred and one thousand hours a year—in Western terms perhaps between ten and twenty weeks a year. This does not

compare badly with Western practice, where perhaps between one-tenth and one-half of the family salary is spent on food. But such a simple comparison is misleading, for it implies that none of us actually works directly any longer to produce food—we merely earn money to pay for it. In fact it is not only the farmers who produce food in our society; far more people are involved in jobs such as chemical engineering, fertilizer production, plant breeding and mechanical agricultural equipment production, maintenance and servicing—not to mention the supply and distribution of fossil fuels on which all these depend. We are wont to think that we have succeeded in drastically reducing the number of man-hours required to produce food. And to some extent we have—but the reduction is much less marked if all the various jobs on which agriculture is dependent are taken into account.

But in fact this kind of justification for swidden farming is not really needed. There is plenty of evidence from the field. For example, the Finno-Ougrian peoples in nineteenth-century Europe are said to have produced a rye yield three to four times as high by slash and burn as is possible with continuously cropped fields. Reports have been made that irrigated rice agriculture is less than half as productive as swidden farming in terms of man-hours. And there are plenty of examples of people who have been persuaded to change their system to continuous cropping, only to revert to swidden farming a few years later when they find the old system more productive in terms of both food quantity and man-hours involved. In some cases in Vietnam, agricultural peoples who were traditionally ploughers have given up their ancestral methods in favour of the swidden.

But it does remain a fact that swidden farming can support only a limited population density. In the past, this factor has been grossly exaggerated, and used as an argument for immediate "advance" to continuous cropping methods. The facts are now better known and generally support the idea that a swidden people need six to seven acres of forest per head of population. Higher densities than this are known, but so are lower ones. For comparison, the world average of arable and pasture land is currently about two and a half acres a head. But what we should remember is that swidden farming is now practised largely in tropical or sub-tropical areas, which are certainly not the areas of tremendous fertility which is their popular image. As we have said, the soil is poor and attempts to introduce other forms of farming have often failed; and though there may be ways to increase the productivity of swidden farming, we have not found them yet. Certainly, we could not immediately increase world food production by ploughing up the tropical forests and planting suitable grain; the result would be a catastrophe, for Western forms of agri-

culture are quite unsuitable for the tropics. Indeed, it is extremely doubtful that our own form of agriculture is at all suitable for any planet as perilously near starvation as we have been for the past three decades.

The Western world is addicted to meat. For us, no meal is considered a real meal unless it includes animal protein and nearly all our large-scale farming is directed towards meat production in one form or another. Now, we do not intend to indulge in any sentimentality over the question of exploiting and killing animals in this way; neither we nor the primitive could afford any such luxury. But there are many little-known facts that lie behind our obsession with meat-eating which contrast starkly with primitive habits, and with our global demand for better food.

No man needs meat to survive—a perfectly adequate diet can be assembled from plant protein. To do so is, however, technically rather difficult, and a portion of meat in a diet is medically advisable. The great question is how much? Two beefsteaks a day? Or meat when you can get it, as in many primitive hunting and gathering societies? Or maybe meat twice a week?

One of the golden rules of ecology is that the higher up the food chain one eats the less efficient is the overall process. For maximum efficiency we should be able to convert the sun's energy and carbon dioxide in the air into protein ourselves. Of course we can't—but plants can. And animals obtain their nutrient requirements either by eating plants directly or by eating other animals which themselves are herbivores. The logic of eating well down in the food chain is easy to see from the following figures. For every pound of protein in a hen's eggs, that hen has had to eat 4.3 pounds of plant protein. For milk the figure is 4.4, for chicken meat 5.5, for pig 8.3 and for beef 21. In other words, a given area of farmland can either be used to provide the beef protein necessary for one person, or the equivalent in plant protein for twenty-one people. Thus by concentrating so exclusively on meat we have in a sense thrown away the advantages accruing from the increased production of modern farming.

In the United States the average mix of animal protein eaten is such that one person's diet of protein could have provided the plant protein needed to feed eight people. One acre of cereals will provide five times more protein than if that field were used for beef production. An acre of legumes provides ten times more, an acre of leafy vegetables fifteen times and an acre of spinach twenty-six times more. To cap it all, in a world where water shortage is imminent if not actual, a mixed beef and grain diet requires eight times the volume of water needed for the equivalent diet of grain only.

Yet in the West, a journey to the country reveals huge areas or grain ripening in the sun. It would seem that this was a step in the right direction. Not at all, for 78 per cent of that grain is fed directly to animals to provide animal protein in the form of beef and ham and veal. Excluding dairy cattle, in 1968 twenty million tons of edible plant protein were fed to domestic animals in the United States, of which a portion ended up on the dinner-table at a huge protein loss. In fact it has been calculated that if this grain were used directly, the protein saved would have provided 90 per cent of the yearly global protein deficit at that time. As Lyle P. Schertz has put it, "the billion people in the developed countries use practically as much cereals as feed to produce animal protein as the two billion people in the developing countries use directly as food". The situation is made worse by the fact that beef cattle are fed for their fat, most of which is then thrown away. Or rather it is exported back to the developing countries as inedible grease in return for edible plant protein or edible fish protein which is then fed to cattle to continue the vicious circle.

The more one investigates this quagmire of waste, the deeper one sinks. To provide the huge output of meat which the West now thinks it requires, it exploits not only the Third World but its own land as well. Pressures on productivity are so acute that over-grazing and over-ploughing are common, with the result that, according to Georg Borgstrom, the United States has now lost one quarter of the top soil it had when the prairies were first ploughed. The savage rape of the land that is now carried out in the name of farming makes a sharp contrast with that of the primitive swidden farmer, whose exuberance in burning down one-third of an acre of forest per man every year, to allow it to grow again after two years, has been attacked as wasteful by our own agriculturalists. Yet the primitive was far nearer a stable and ecologically viable situation than we are. Without so much as help of an acid indicator kit, he could distinguish ten basic and thirty derivative soil and mineral categories. Today's farmer merely calls in the nearest fertilizer firm to advise him on how much energy-intensive chemicals he should apply this year. And most years the figure quoted is higher than in the previous one.

In fact, this waste is greatest of all when the energy balance is considered. Today the energy input to food production is enormous. Energy is used in making fertilizer; in producing pesticides and herbicides; in fuelling tractors, combine harvesters, drying machines, hedge croppers, ditch diggers, and a thousand other tasks. As a result our productivity has gone up, and to many it appears that we have learned how to use the sun's productivity more efficiently. "This", writes the ecologist Howard T. Odum, "is a sad hoax, for in-

dustrial man no longer eats potatoes made from solar energy; now he eats potatoes partly made of oil."

Perhaps there would be little to criticize in this if our energy sources were more carefully chosen than they are. But they still consist mostly of fossil fuel ripped from the Earth's belly with careless cuts, which never heal and which sink deeper every year towards the bottom of a barrel which is already beginning to show. Soon there may be little more where the last lot came from. What then? Odum writes:

"The citizen in the industrialized country thinks he can look down upon the system of man, animals, and subsistence agriculture that provides some living from an acre or two in India when the monsoon rains are favourable. Yet if fossil and nuclear fuels were cut off, we would have to recruit farmers from India and other underdeveloped countries to show the now affluent citizens how to survive on the land while the population was being reduced a hundredfold to make it possible."

Such an idea is not as extraordinary as it may sound. With—until now—access to all the energy it needs, Western agriculture has been slowly but surely turned into a vast industrial business, where profit and loss rule the working day and the planting schedule. We have forgotten that agriculture is basically a means of growing food, utilizing the free energy of the sun. Now that our other energy sources feature so much more importantly in the agricultural equation, there are those who argue that we should forget agriculture altogether. Food—or perhaps it would be better called nutrition—could be grown in factories where the sun never entered because its energy would be replaced by the giant output of a nuclear reactor. If, in the future, such a system becomes more profitable, it may well be adopted; and soon after agriculture would be relegated to the folk museum, along with such antique crafts as cobbling, weaving and smithying.

Any subsequent crisis in energy supply would, of course, then affect much more than the production of automobiles. We would have to learn again, and quickly, the ancient art of farming, with imported instructors who had been lucky, or unlucky, enough not to have had the chance to go nuclear. Even today, such advice might be highly interesting. No doubt a primitive farmer who surveyed our own agricultural practices, and the international trade system on which they were based, would see immediately how we managed such an enormous productivity yet produced so many hungry people. Like Francis Moore Lappe in her *Diets for a Small Planet*, he would direct our attention away from animals and back towards the plants that make so much more efficient use of both land and sun. He would puzzle over the system we had invented for helping the hungry

countries, which consists essentially in importing their higher quality proteins and paying for them by returning lower quality proteins. But in the end he would probably single out one very practical guide to the future. "Stop trying to grow money," he would advise, "and start trying to grow food". (Taken from, *The Challenge of the Primitives.* 1975. pp.32-41).

"Agribusiness" as Orthodoxy

By Wendel Berry

Not all agricultural economists are blind to the human and ecological consequences of "agribusiness" economics. On March 1, 1972, Professor Philip M. Raup, of the University of Minnesota at St. Paul, testified as follows, before the Subcommittee on Monopoly of the United States Senate Small Business Committee:

"Only in the past decade has serious attention been given to the fact that the large agricultural firm is able to achieve benefits by externalizing certain costs. The disadvantages of large scale operation fall largely outside the decision-making framework of the large farm firm. Problems of waste disposal, pollution control, added burdens on public services, deterioration of rural social structures, impairment of the tax base, and the political consequences of a concentration of economic power have typically not been considered as costs of large scale, by the firm. They are unquestionably costs to the larger community.

"In theory, large-scale operation should enable the firm to bring a wide range of both benefits and costs within its internal decision-making framework. In practice, the economic and political power that accompanies large size provides a constant temptation to the large firm to take the benefits and pass on the costs.

"The rural community receives the immediate impact of this ability of large farm firms to practice selective internalization of benefits and externalization of costs. One of the most pervasive consequences is that the occupational composition of the population changes. Instead of a large number of small entrepreneurs, combining the functions of manager and laborer, the occupational structure includes a small number of managers and a large number of workers. In rural communities dominated by very large firms, the settlement and housing patterns reflect the increasingly transient nature of the labor force. The symbol of the large corporate farm becomes the trailer house. Community institutions suffer from lack of leadership,

and from the lack of sense of commitment on the part of the labor force to long-run community welfare. Those institutions that survive take on a dependent character, reflecting the paternalistic role of the dominant firms. Income levels may stabilize, but at the expense of a decline in local capacity for risk-taking, decision-making, and investment of family labor in farms and local businesses."

And later in his testimony, Professor Raup spoke of the most ironic of these "externalized" costs: "Farmers who have succeeded in increasing their farm size to a scale that will enable them to achieve almost all of the economics of size in production now find that their capital structure is so large that their sons cannot finance a takeover of the family farm."

Professor Raup's distinction between internal and external accounting is of great usefulness in understanding our problem. It is by internal accounting that the modern American agricultural program may be thought "the best, the most logical and the most successful". External accounting brings us to a very different conclusion. External accounting pushes us back into our moral tradition, which asks us to consider that we are members of the human community and are therefore bound to help or harm it by our behavior. This sort of accounting involves much more than economics. It is broad and difficult, and it eludes quantification.

Modern American agriculture has made itself a "science" and has preserved itself within its grandiose and destructive assumptions by cutting itself off from the moral tradition (as it has done also from the agricultural tradition) and confining its vision and its thought within the bounds of internal accounting. Agriculture experts and "agribusinessmen" are free to believe that their system works because they have accepted a convention which makes "external," and therefore irrelevant, all evidence that it does not work. "External" questions are not asked or heard, much less answered. (From, *The Unsettling of America: Culture and Agriculture*, 1977. pp.171-172).

A Pre-Industrial Example

By looking at an example of a sound pre-industrial agriculture we can get a sense of its ecological and cultural coherence and its geographical responsiveness and also a sense of its careful relationship to its margins. Perhaps no more vivid example exists in our time than that of the native agriculture of the Peruvian Andes. I take the following summary from an unpublished paper by Professor Stephen B. Brush, of the Department of Anthropology at the College of William and Mary.

Professor Brush's study focuses on the village of Uchucmarca in a valley in northern Peru. This valley has "one of the steepest envi-

ronmental gradients in the world". Like other Andean farmers, the people of Uchucmarca farm in four different climatic zones, requiring four different kinds of agriculture:

"1. a tropical zone...which produces fruit (such as oranges and bananas), tropical root plants (such as manioc), chile peppers, and perhaps most importantly coca...

"2. a middle level mountain zone...where maize and wheat are grown...

"3. a relatively high mountain zone...where the staple of the Andean diet, potatoes, and other Andean tubers are grown...

"4. a high mountain zone...where llamas, alpacas, sheep, horses, and cattle are grazed on natural pasture..."

Within a distance of forty miles the valley rises from "roughly 3,200 feet" to "over 14,700 feet"—thus including a diversity of climates as great as that from west Texas to Alaska. The natives of the valley "recognize and name seven different production zones...which are variations on the four major zones."

The agriculture of the valley is based upon a highly evolved awareness of the nature of each of these climatic zones and of the differences among them. It involves a careful balance between the use and the maintenance of productivity. Professor Brush says that "The village economy may be understood as a set of subsistence strategies designed to provision each household with adequate food.... One of the most important features of the local economy is that it is able to function as a largely nonmonetized economy. The average family in Uchucmarca needs less than $100 yearly..." It is significant that the verb in that last sentence is "needs", where "agribusiness" assumptions would require "has only." The governing concept of the agriculture of these Andean peasants, then, is enough, a long-term sufficiency, whereas the governing concept of ours is profit or affluence, without *regard for long-term needs*.*

Like most farmers, those of Uchucmarca must cope with the hazards of erosion, frost, too much or too little rain, pests, and diseases. They do this very effectively and without recourse to the industrial technology of machines and chemicals.

"The danger of erosion is avoided in three ways. First, fields are kept small—usually less than one acre. A typical family of four to five persons cultivates between three and four acres, spread among

*In a letter to me, dated February 15, 1977, Professor Brush wrote as follows: "... I calculate that with their 'primitive' agriculture, the farmers of Uchucmarca produce 2700 calories and 80 grams of protein (vegetable) per capita per day. A very good diet and a well fed population. The worst malnutrition occurs in cities where people must depend on 'modern' agriculture."

as many fields. The small size of individual plots retards run-off and erosion. Second, each field is surrounded by a hedgerow constructed of rocks, brush, and living plants. Ostensibly built to keep out destructive livestock, these hedgerows effectively limit erosion. Their roots hold the soil, and horizontal plowing behind them tends to build up soil at the lower side of the field. This creates a quasi-terrace or lynchet...Third, field rotation is practiced in the highest and steepest part of the valley where rainfall is heaviest and erosion most likely. Potatoes are cultivated under a regime of shifting cultivation in which fields are only planted for two or three years before being returned to a long fallow of five years or more. By using this method, the amount of soil washed off of fields is limited, and organic material is allowed to reaccumulate."

The people of Uchucmarca cope with climatic variations by "the exploitation of multiple zones and crops", so that if one crop fails they may rely on one of a different kind. "Another way is to plant several different fields of the same crop, hoping that if one field is destroyed, the other will survive. These means are reinforced by systems of economic reciprocity and mutual dependence which rely primarily on the kinship system." Within families, "individual households protect themselves from privation by exchanging land, labor, and goods."

Against insects and diseases, the main weapon of the Andean peasants is genetic diversity: "Botanists estimate that there are well over 2,000 potato varieties in Peru alone. In single villages like Uchucmarca people identify some fifty varieties..." And here we arrive at the greatest complexity, versatility, and responsiveness of this agriculture, as well as its most intense sensitivity to place. For these varieties are not used at random, but are delicately fitted into their appropriate ecological niches. "In Uchucmarca, a common practice is to plant fast growing varieties during the drier part of the year so as to avoid late blight which increases during the months of heavy rain. Another practice is to cultivate certain varieties believed to be somewhat frost resistant in flat, bottom areas of the high valley where frost but not late blight is common. Other varieties are chosen for hillside cultivation where late blight but not frost is common." Varieties are also chosen according to how well they do at certain altitudes or according to whether or not they need a soil that drains well. Of course, this description gives only a rough idea of the intricacy of possible adjustments among so many varieties and so many kinds of ground.

Professor Brush's work makes it plain that nearly all the methods of the Andean farmers are based upon the one principle of diversity. In their understanding and use of this principle, they have developed an agriculture much more sophisticated, efficient, and con-

servative of the soil than our own—and one that is also much more likely to survive a crisis. How finely this agriculture is attuned to the needs and circumstances of the community becomes apparent when Professor Brush describes recent attempts to change it by the introduction of industrial technology and "improved" potato varieties. Such change involves a gross simplification of the agriculture itself as well as a drastic complication of the economy. It requires a cash economy and credit, favors the larger producers, and threatens to destroy both the human community and the ecological viability of a farming system that is "the result of thousands of years of natural and human selection".

But the sophistication and durability of Andean agriculture cannot be fully appreciated until one has understood the way it utilizes—indeed, depends upon—its margins. The fifty potato varieties used in Uchucmarca are not a stable quantity, but rather a sort of genetic vocabulary in a state of continuous revision. Professor Brush says that "new varieties are constantly being created through cross-pollination between cultivated, wild and semidomesticated (weedy) species...These wild and semidomesticated species thrive in the hedgerows around fields, and birds and insects living there assist cross-pollination." Thus, if an Andean farmer loses a crop because of an extremity of the weather or an infestation of insects or disease, he may find a plant of a new variety that has survived the calamity and produced in spite of it. If he finds such a plant, he may add it to his collection of domesticated varieties or substitute it for the one that has failed.

This Andean agriculture, then, does not push its margins back to land unsuitable for farming, as ours does, but incorporates them into the very structure of its farms. The hedgerows are marginal areas, little thoroughfares of wilderness closely crisscrossing the farmland, and in them agriculture is constantly renewing itself in direct response to what threatens it. This network of wilderness threading through the fields serves the Andean farmer as a college of agriculture and experiment station. And in at least one respect it serves him better: whatever is discovered there has already been tested in the circumstances of the farm itself, and its worth or worthlessness proven. The farmer, in whose mind culture and agriculture are wedded, acts as both teacher-researcher and student, both extension agent and client. Set thus in the light of a truly healthy agriculture, our land-grant college complex may be seen less as a symbol of our agricultural success than as a symptom of our failure. (pp.175-178)

Organic Farms

The attitudes and values of traditional agriculture still survive in our time and are supported by the experience of our time. Their survival is marginal and is mostly ignored both by the colleges of agriculture and by the agricultural press, which, if they acknowledge it at all, do so in order to treat it with contempt. But survivors do exist. They are connected by a sort of network that one travels by hearsay and friendship. By now I have encountered a good many of them, and have been impressed as often by the excellence of their characters as by the excellence of their farms. They are people of principle, both stubborn and adventurous, independent enough to trust their own experience and strong enough to hold in considerable isolation to truths not officially or popularly favored. Their farms stand for their principles and prove them; one has only to notice their example, or their examples, to understand that the orthodox agriculture has founded its "scientific proofs" upon shallow assumptions.

In spite of some public notice in the last year or two, it probably still is not generally known that there are a number of large-scale, highly mechanized farms that do not use chemical fertilizers or pesticides. When I first began my search for examples of healthy agriculture, I did not realize how compatible organic soil management could be with a large scale of operation.

And then in the spring of 1974, I visited a 900-acre organic farm in Iowa. This farm made extensive use of a commercial organic fertilizer. But that seemed to me probably the least important element of the farming there. More important, I thought, were a careful plan of crop rotation (corn for a year or two, oats, soybeans, and then two years of pasture), the use of animal manure on corn ground every year, and the use of a chisel plow rather than the conventional turning plow for the preparation of crop ground.

This system was said to have the following advantages: within the first year or two of its use, earthworms and other forms of life had again become abundant in the soil; the ground had become darker, looser, easier to work each year; crops could be planted earlier because the increased humus in the soil permitted it to dry more quickly; stock feed went farther every year, because as it became more palatable and nutritious it took less to satisfy the cattle; the farm had no insecticide program at all, either for crops or stock.

In its machinery, buildings, etc., this farm was as "modern" as any other of comparable size. Even though it was far more diversified than most large farms of these times, and did not use chemical shortcuts, it required only four full-time workers. Late in 1975 I visited another highly mechanized organic farm—this one a 700-acre farm in Nebraska—another extremely impressive example of organic

farming on a large scale. The existence of such farms as these, on which crops, animals, and the farmers themselves are obviously thriving, invalidates out-of-hand the contempt of orthodox agriculturists and suggests strongly that their contempt must rest on ignorance or fright.

If all the farms in the country were managed organically, both our people and our land would undoubtedly be healthier and there would be a considerable ramification of the benefits. And yet the 700- or 900-acre organic farm equipped with up-to-the-minute machine technology cannot be considered the solution to all of our agricultural problems, or to the problems that grow out of our agricultural problems. If we accept this as a solution, we forswear, for one thing, any further discussion of the cultural and political importance of the small landowner.

Much more suggestive, in this light, was another Iowa farm that I visited, this one a family-size holding of 175 acres. Of this, 50 acres were in permanent hillside pasture for twenty-eight Charolais cows. On the remaining 125 acres, the farmer grew corn, oats, wheat, soybeans, and hay. In addition to his cow herd, he kept twelve brood sows and a laying flock of 200 hens.

This farm had been under a completely organic system of soil management for eleven years at the time I saw it in 1974. Here again some commercial organic fertilizer was used to supplement a careful plan of soil husbandry. The cycle of crop rotation was as follows: oats and/or wheat, legumes for hay, soybeans, corn. The application of animal manure was estimated (conservatively) at two tons per acre, and this was put on the bean ground before planting it in corn. The expenditure for commercial fertilizer, which was used only on the corn ground, came to twelve dollars per acre. Every three years or so the pastures were dressed with 300 pounds per acre of a natural mineral fertilizer.

The farmer here was a man of impressive intelligence and judgment and impressively independent in both. Prescribed measures had been altered as he felt necessary to fit his place and his needs. The secretary of agriculture had called for all-out production that year, and on many farms the plowlands had begun to edge out dangerously into waterways and hillside pastures. I asked this farmer if the secretary's recommendation had affected his program. He answered that it had not done so in the least.

On this farm I first had a chance to watch a chisel plow at work and to see the ground it had prepared. This is a favorite tool of many mechanized organic farmers, who give it enthusiastic praise. I could see why. To begin with, it does all the work of seed-bed preparation, replacing both turning plow and harrow. But its great

advantage is that it leaves the top layer of soil on top, which is where it belongs. Loosely stirred into this top layer, animal manures and plant residues decompose aerobically. The resulting high content of organic matter causes the surface of the field to act as a sponge, readily absorbing and retaining water and also allowing it to percolate downward into the lower layers. Another advantage of this plow is that it does not cause a hardpan; it does not interfere with the downward course of water through the pores of the soil, worm holes, and old root channels deep into the subsoil. The result is that the soil becomes at once less drouthy and less subject to erosion. It also becomes looser, easier, and cheaper to work with, and so operating money goes farther and machinery lasts longer. On this farm, sod ground to be broken is plowed once with the straight chisels in the fall and is then plowed twice again with sixteen-inch sweeps in the spring before planting. These sweeps are very good for destroying deep-rooted weeds.

This farmer used no herbicides. The reason he gave was that he did not want to contaminate the streams. But he also appeared to have no great need for such chemicals. He tried to plant in the latter part of the planting season so as to allow more weeds to germinate and be killed in the preparation of the ground. He cultivated his row crops to remove large-stemmed weeds, and he found that taking three cuttings a year from his hay fields helped considerably to control weeds in the row crops that followed.

As for crop yields on this farm, I quote the following from a letter that the farmer wrote to me several months after my visit: "I would say our soy beans average 40 or more bu. per acre in an average year. The state average is 30 to 33 bu. Our corn has been yielding 90 to 100 bu. the past 5 years. Neighbors' yields are about the same for the same soil type and lay of land. Our wheat yielded over 25 bu. per acre which we feel is very good for this area...Our oats have been 60 bu. on the average."

The cow herd on this farm was given a balanced mineral mixture as a supplement but was wintered on hay alone, without grain. No insecticides were used on the cattle. The farmer wrote that although his cattle have flies on them in the summertime, they do not have pinkeye or other eye problems usually associated with flies. He attributed this to their extraordinary good health. In December of 1974, he wrote me that the twenty-three March and April calves of this herd weighed variously from 400 to 700 pounds per head. These calves were in robust health, without pinkeye or any other disease.

Another mechanized organic farm is the new experimental farm belonging to Rodale Press, publisher of *Organic Gardening and Farming*. In 1972, 290 acres of this farm were rented to an excellent Mennonite farmer, who agreed to operate it according to strict or-

ganic principles. A five-year rotation cycle was set up (corn to rye to barley to wheat to timothy and clover) with twelve tons of manure per acre to be applied to the corn ground. The crops were planted in strips on the contour. Before 1972 this farm was cropped in the orthodox fashion, using heavy applications of chemicals, and the following corn-production figures are especially interesting for that reason. (Figures are available only for corn.) In the first year the yield was 40 bushels per acre; in the second year, 60; in the third year, 80; in the fourth year, 140. In that fourth year the top yield in the same county was 157 bushels per acre—obtained with an application of 190 pounds of nitrogen, 230 pounds of phosphorus, and 673 pounds of potassium.

Barry Commoner's Argument

There is, then, no way to deny that crops and animals can be produced in respectable yields by the methods generally designated as "organic". These methods work on large farms and on small ones. Available evidence indicates that they work at least as well as orthodox methods within the economy of the individual farm, and they will undoubtedly work better as the costs of chemical fertilizers, pesticides, and herbicides rise with the cost of petroleum. But perhaps the greatest benefits from the widespread adoption of organic methods of soil management would go to the general public—in greatly reduced soil and water pollution, in reduced public expenditures for pollution control, in better health, and at least eventually in cheaper food.

The abounding good health of the firms I have described is dramatically evident to an experienced observer. I believe that it would be just as evident to an inexperienced observer who would spend a few hours looking closely and comparing. But in support of the visual impression we now have some evidence from the Center for the Biology of Natural Systems at Washington University—a report published in 1975 and entitled *A Comparison of the Production, Economic Returns, and Energy Intensiveness of Corn Belt Farms That Do and Do Not Use Inorganic Fertilizers and Pesticides.* In *The Poverty of Power*, Barry Commoner makes this study the fulcrum of a powerful argument for organic soil management. I am going to make extensive reference to Dr. Commoner's argument both because it supports and completes my own and because I want to take issue, a little further on, with one of his assumptions.

Dr. Commoner begins by going over some ground often traversed by the specialists and apologists of orthodox agriculture, but he goes further and sees much more clearly. From 1950 to 1970, he acknowledges, American agriculture made some impressive increases

in productivity: corn production per acre tripled; "a broiler chicken gained nearly 50 percent more weight from its feed"; egg production increased by twenty-five percent; overall farm production "increased by 40 percent". But during that period the real farm income "*decreased* from about $18 billion in 1950 to $13 billion in 1971...Because the number of farms also decreased by 50 percent, the income per farm rose by 46 percent...However...the average increase in the family income of *all* U.S. families in that period [was] 76 percent. Meanwhile, the total mortgage debt of U.S. farms rose from about $8 billion in 1950 to $24 billion in 1971." During this time there was also a massive shift from diversified farming to monoculture, which reduced the time that the farmland was covered with plant growth, which in turn reduced the amount of solar energy put to use on the farm. The removal of animals from farms growing crops in monocultures reduced the amount of organic waste returned to the fields. And there was a shift from the use of nitrogen-fixing legumes to the use of commercial nitrogen fertilizers. From 1959 to 1973 there was a sixty-percent decrease in the production of legume seed. By these and other changes, "The farm's link to the sun has been weakened, replaced by a new and...dangerous liaison with industry." And this dependence on sources of energy of the farm explains the decline of farm income. The net farm income decreased from 1950 to 1970, not in spite of, but *because of* the new technology of machines and chemicals. Dr. Commoner concludes his analysis of the effects of this technology with the following indictment:

"One can almost admire the enterprise and clever salesmanship of the petrochemical industry. Somehow it has managed to convince the farmer that he should give up the free solar energy that drives the natural cycles and, instead, buy the needed energy—in the form of fertilizer and fuel—from the petrochemical industry. Not content with that commercial coup, these industrial giants have completed their conquest of the farmer by going into competition with what the farm produces. They have introduced into the market a series of competing synthetics: synthetic fiber, which competes with cotton and wool; detergents, which compete with soap made of natural oils and fat; plastics, which compete with wood; and pesticides that compete with birds and ladybugs, which used to be free.

"The giant corporations have made a colony out of rural America." Dr. Commoner then turns to the organic farmers studied by the Washington University research group, of which he was a member. He sees in the methods of these farmers the obvious solution to the problem:

"The group analyzed the production of these farms for the 1974 season. The market value of the crops produced by the conventional farms was an average of $179 per acre, while the average value for

the organic farm was $165 per acre. However, the operating costs of the conventional farms averaged $47 per acre, and those of the organic farms $31 per acre (the difference is largely due to the cost of the nitrogen fertilizer and pesticides used by the conventional farmers). As a result, the net income per acre of crop for the two types of farms is essentially the same...The yields of different crops obtained by the two groups of farms are about equal, except for a small excess (12 percent) of corn yields on conventional farms as compared with organic farms.

"The organic farms used only 6800 BTU of energy to produce a dollar of output, while the conventional farms used 18,400 BTU. Thus, organic farms appear to yield about the same economic returns as the conventional ones, but do so by using about one-third as much energy."(pp.193-199)

The Amish

My final example of an exemplary marginal agriculture is that of the Amish. Nothing, I think, is more peculiarly characteristic of the agricultural orthodoxy—as of American society in general—than its inability to see the Amish for what they are. Oh, it *sees* them, all right. It sees them as quaint, picturesque, old-fashioned, backward, unprogressive, strange, extreme, different, perhaps slightly subversive. And that "sight" is perfect blindness. What is not seen is that the Amish are a community in the full sense of the word; they may well be the last surviving white community of any considerable size in this country. And for this there are reasons. It is especially the reasons that we do not want to see, for these reasons invalidate most of the assumptions and ambitions by which we proudly characterize ourselves as "modern".

My knowledge of the Amish, as of the other farmers I have discussed, is by no means thorough or detailed enough to satisfy the demands of strict scholarship. And I shall not pretend to be "objective" about them. I admire and respect them deeply, with few reservations; in many ways I envy them. In addition to reading several published accounts of Amish culture and agriculture, I am able to speak to some extent from experience. I have looked carefully at Amish farming in Iowa, Pennsylvania, Indiana, and Ohio, and these travels have involved some personal contacts.

What, then, are the reasons that the Amish have been able to survive as a community—or, it might be more correct to say, as a closely bound fellowship of many communities? I think that there are three primary reasons, from which spring many others.

First, the Amish communities are, at their center, religious. They are bound together not just by various worldly necessities, but by

spiritual authority. Theirs is, moreover, a religion unusually attentive to its effects and obligations in this world. Whereas most contemporary sects of Christianity have tended to specialize in the interests of the spirit, leaving aside the issues of the use of the world, the Amish have not secularized their earthly life. They have not hesitated to see communal and agricultural implications in their religious principles, and these implications directly influence their behavior. The "goal" of Amish culture is not just the welfare of the spirit, but a larger harmony "among God, nature, family, and community".*

Second, the Amish have severely restricted the growth of institutions among themselves, and so they are not victimized, as we so frequently are, by organizations set up ostensibly to "serve" them. Though they pay the required deferences to our institutions, they accept few of the benefits, and so remain, in perhaps the most important respects, free of them. They do not become dependent on them and so maintain their integrity. As far as I know, the only institutions in our sense that the Amish have started are their schools—and this, by our standards, for a strange reason: to *keep* the responsibility for educating their children and so, in consequence, to keep their children. Amish ministers and bishops are chosen by lot, after fasting and prayer (as Mathias was chosen), and so they do not have a professional, a paid, an economically dependent, or an ambitious clergy. Their religious services are held in barns or homes; their charities are not organized or abstract but are usually in direct response to observed needs. And so they do not have a church building or a building fund or church functionaries or administrators. There is little distinction between the church and its members.

There are, one may as well say, only two Amish institutions: the family and the community. And these institutions fulfill directly, humanly, simply, and quietly nearly all the functions that we have delegated to our obtrusive, inhuman, indifferent, clumsy, expensive institutions. Family and community serve as insurance, welfare, social security, public safety. Indeed, they serve as, and replace, government. The simple living together of relatives and neighbors makes unnecessary to them our obsession with "security".

Third, the Amish are the truest geniuses of technology, for they understand the necessity of limiting it, and they know how to limit it. They have refused to see "technological innovation as an end in

*The Amish have two considerable problems, now, which trouble this ideal of harmony. They are having more children than, in present economic conditions, they can provide farms for, and so some of their young people are taking town jobs. And where coal underlies their land, some are permitting the strip-miners to come in. Reclamation was better than usual on the Amish farms I saw that had been stripped, and the land was going back into pasture. Some Amishmen nevertheless feel the practice to be wrong.

itself". And so their "religiously enforced family and community values are safeguarded against the social costs of changes which in their estimation did more harm than good to the community as a whole". Whereas our society tends to conceive of community as a loose political-economic mechanism of mutually competing producers, suppliers, and consumers, the Amish think of "the community as a whole"—that is, as all of the people, or perhaps, considering the excellence both of their neighborliness and their husbandry, as all the people and their land together. If the community is whole, then it is healthy, at once earthly and holy. The wholeness or health of the community is their standard. And by this standard they have been required to limit their technology.

By living well without such "necessities" as automobiles, tractors, electrical power, and telephones, the Amish prove them unnecessary and so give the lie to our "economy". And by these restraints they have kept their health, for by them they have kept themselves at home and have, for the most part, kept their children at home. They have not the knowledge of experts, which is by definition a homeless or rootless knowledge—the knowledge, in Sir Albert Howard's words, of people who cannot "take their own advice before offering it to other people"—and which is, as such, dangerous. They do not use knowledge to prey upon one another.

The healthy results of these restraints are readily visible to anyone who so much as drives an automobile through an Amish community. Unlike so much of the best farmland, which has become a kind of agricultural desert, the Amish landscape is vibrantly populated with both people and animals. Busy people are seen everywhere. All the houses are lived in. All the buildings are in use. Fences and buildings are in excellent repair. And there are signs of a thriving and thrifty home life: vegetable gardens, flower gardens, fruit trees, grape arbors, berry vines, beehives, bird houses. People are making careful, comely, dignified work of the essential tasks defined by modern values as "drudgery". And because they have thought of the well-being of all the people, all are busy. There is a use for everyone. The Amish do not have the abandoned children, cast-off old people, criminals, indigents, and vagrants whom we have "freed from drudgery".

And these people practice a way of farming capable of taking exquisite care of the land. In the fall of 1976 I stood on a hillside that had been used and cared for by three generations of Amish farmers. It was steep land of the sort more often than not worn out under the old American agriculture and simply unusable by the new. This hillside had been cropped in alternating strips of corn and sod. The corn crop, which was excellent, had been cut with a binder and shocked. The farmer and his sons had carried the bundles off the

plowed ground—eight rows up the hill, eight rows down—and shocked them on the sod strips, so as to get the cover crop sowed as soon as possible. By orthodox standards, this work was demeaning drudgery. By the standard of the health of the field, it was simply necessary, and so it had been done. When I was there the cover crop was coming up to safeguard the ground over the winter. I looked for marks of erosion. There were none. It is possible, I think, to say that this is a Christian agriculture, formed upon the understanding that it is sinful for people to misuse or destroy what they did not make. The Creation is a unique, irreplaceable gift, therefore to be used with humility, respect, and skill.

And so, though Amish agriculture is not modern or progressive, it is by no means ignorant or unintelligent. By the correct standard, it is much more sophisticated than orthodox agriculture. The Amish were among the first to understand the uses of rotation, manure, and legumes. They keep a balance between livestock and crops. They benefit from exchanges of labor and other forms of neighborliness. In lieu of massive consumption of fossil fuels and electricity, they make the fullest possible use of energies available on the farm—of the wind, of draft animals, and, of course, of their own bodies. Their technological restraints are balanced, quite naturally, by inventiveness. The Amish are good mechanics, and they have displayed much ingenuity in, among other things, the adaptation of tractor implements for use with teams of two to eight or more horses.

Another observer of Amish farming wrote a letter to the editor of the *Draft Horse Journal*, who published excerpts in the issue of Autumn 1976. The editor noted that "the writer of this letter owns no horses, has no vested interest in the horse business, that I know of". The following paragraphs are taken from that letter.

"My farming consists of just under a hundred acres of rather heavy, low lying land. At one time our family did something or other on three farms, of which one has gotten completely covered by houses and another has been sold to an Old Order Amishman. We still call the third one home.

"When the one farm was sold to the Amishman I forgot to tell him that one particular field was too heavy and low to grow alfalfa. By experience, I knew it wouldn't work. For a couple of years he had it in other crops, then he went to alfalfa. This embarrassed me because I knew I should have cautioned him on this. But he had a marvelous stand and a very heavy yield. It was puzzling. I puzzled over it for years but am now very persuaded of the why and wherefore.

"With our tractors we kept the soil rather permanently compacted because it was necessary to get on the land as soon as surface moisture conditions permitted. And the tire patterns pretty well

rolled the entire area in the course of repeated passage. With his horses, this just didn't happen. And in the course of a couple of winters the deep frost had corrected my tractor compaction mistakes. Soil structure improved. Root penetration was facilitated. Water holding capacity as well as internal drainage both benefited, and the alfalfa flourished.

The Amish will not argue the point because they don't think anyone is interested, but will say that a farm "works" easier after a couple of years of horse farming. This compaction problem has to be the explanation. The resulting improved soil structure, allowing for better root penetration, is probably the reason they can get similar yields with less chemical fertilizer than their mechanized neighbors.

"But back to that heavy land alfalfa for a moment. The crop was disgustingly rank and lodged. Mowing it would be a problem. So I paid a visit, and...was flabbergasted to notice the farmer slowed down and mowed right through...Then I realized that something very nice was being demonstrated; since the sickle drive was independent from ground travel (his horse drawn mower was equipped with an engine to drive the sickle...) this 'horse farmer' had sickle-cycle-to-ground-speed control that no tractor farmer could have unless he had a hydrostatic drive tractor! It gave him a control flexibility that I had never experienced and left me feeling sort of humble. I came away wondering which of us had the better technology...and I'm still not sure."

And then this writer addresses himself to the standard orthodox argument that we cannot feed draft horses without starving humans.

"Of course you have to feed draft animals. But this does not necessarily mean you'll have less to sell per acre farmed. In my observation, good horse farmers seem to have about as much to market per acre as the rest of us. Certainly they manage to nourish their animals very well, too. Closer examination would probably show the animals are at least partly nourished on what is wasted on fully mechanized farms. I'm not speaking just of corn fodder, either. Who else hand gathers the ears the picker missed now-a-days?...Does the man with the 4 row combine? And could he gather the shelling loss if he would? Hardly.

"Well, I'm not very impressed by the statistics that prove we'd starve if farming went back to animal power. In many sections of the country that is exactly what happens when a farm, or a group of farms, comes into the hands of an Amishman. The farming has gone from tractors back to horses on hundreds of farms in my part of the United States without any noticeable reduction in agricultural output. Any suggestion that our county produces less now than 20 years ago would seem outrageous to all the people I know."

In support of these impressions of the general good health of

Amish agriculture, some more specific information is available in an article entitled "Agricultural Alternatives" in the March-April 1972 issue of *CBNS Notes*, published by the Center for the Biology of Natural Systems. I take the following quotations from that article:

"Amish attitudes toward fertility maintenance are amazingly varied...Preliminary analysis of the data shows three distinct patterns. The traditional pattern consists of crop rotation which includes nitrogen-fixing legumes, heavy application of manure to at least 1/5 of the farm in any growing season and lime and rock phosphate to one of the fields in the rotation every year. With the aid of hybrid seed corn some farmers estimate their yields at 90 to 100 bushels per acre although some estimates fall as low as 70.

"A second pattern is the conventional with Amish modifications. The soil will be tested for its acidity and for its phosphorous and potash balance. A county agent or a fertilizer dealer will then make a recommendation for lime and fertilizer application in relation to specific cropping plans. This can include the use of anhydrous ammonia as a cheap source of nitrogen for corn. It is observed that Amish operators who follow this pattern 'factor in' the effects of their crop rotation and the availability of manure and thus apply fertilizer less heavily per acre...

"The third pattern is the use of organic fertilizers...Some of them tend to be costly in terms of additional yield per acre but a minority of the Amish farm operators are very enthusiastic users. The appeal is on the basis of a claim to a more nutritious quality of feed grain which in turn leads to healthier livestock, healthier soil and eventually healthier humans. Interestingly, several of the operators interviewed adopted a program of organic fertility maintenance after having been on a conventional program of commercial fertilizer for several years."

As for the effects of this agriculture, the article offers evidence which suggests that, ecologically and economically, the Amish methods are sounder than the orthodox. Water pollution from Amish fields was far less: "One of the comparative samples taken in March, 1971 showed concentrations of nitrate nitrogen of 12.1 ppm and 8.9 ppm in the tile of conventional farms in Douglas County [Illinois]. The Amish tile had a concentration of 4.6 ppm (corn). A comparison in May showed a concentration of 26.6 ppm (corn) and 10.9 ppm (beans) in the conventional farms and 4.6 ppm in the tiles of the Amish farmer."

And the Amish, whose farms in 1965 averaged only 76.55 acres, were prospering financially during a time when many of the smaller orthodox farmers (with far larger holdings) were being "squeezed out": "Our best single indicator of economic viability is bank data which compares 88 Amish bank accounts in 1964 with those same

accounts in 1971. During these years the Amish accounts showed an increase in net worth from $2,379,000 to $4,045,000."

Since the Amish are manifestly excellent farmers, and are so complexly successful in other ways, one wonders why they have been ignored by the officials and the scholars of agriculture—especially since their technology and methods are so well suited to land not even farmable by orthodox methods and to farmers not able to survive in the orthodox economy. I have been able to think of only two answers, aside from the conventional contempt for anything small: first, the Amish are a thrifty people, hence poor consumers of "purchased inputs" from the "agribusiness" industries; and, second, they are living disproof of some of the fundamental assumptions of the orthodoxy.

To these exemplary forms of unorthodox agriculture, we may add the new work in urban homesteading, aquaculture, solar greenhouses, alternative energy sources, small technology, organic pest control, etc., by the New Alchemy Institute, the Farallones Institute, Rodale Press, and others, as well as the various farmers' and consumers' cooperatives that have been started in the past few years both as strategies of health and as protests against the "agribusiness" juggernaut. Together, these have restored a sense of possibility, both cultural and agricultural, that has been nearly obliterated by the ambitions of agriculture specialists and businessmen. They make possible a vision of an agriculture many times more versatile and diverse than the orthodox, hence many times more responsive to the demands of good husbandry, to local conditions, and to human needs.

For the orthodox obsession with production, profit, and expansion, this healthier agriculture would substitute a more complex consciousness, the terms of which would be ecological integrity, nutrition, technological appropriateness, social stability, skill, quality, thrift, diversity, decentralization, independence, usufruct. Or, put more simply, it would replace the concern for production with a concern for reproduction. Production, some would say, is the male principle in isolation from the female principle. Thus isolated, the male principle wants to exert itself absolutely; it wants to "do everything at once"—which is, of course, what doomsday will do. But reproduction, which is the male and the female principles in union, is nurturing, patient, resigned to the pace of seasons and lives, respectful of the nature of things. Production's tendency is to go "all out"; it always aims to set a new record. Reproduction is more conservative and more modest; its aim is not to happen once, but to happen again and again and again, and so it seeks a balance between saving and spending. At their best, farmers have always had this ancient purpose of reproduction. Without it, they make their art as sterile as mining. (From *The Unsettling of America.* 1977. pp.210-217).

The Secret Life of Plants

By Peter Tompkins and Christopher Bird

Short of Aphrodite, there is nothing lovelier on this planet than a flower, nor more essential than a plant. The true matrix of human life is the green sward covering mother earth. Without green plants we would neither breathe nor eat. On the undersurface of every leaf a million movable lips are engaged in devouring carbon dioxide and expelling oxygen. All together, twenty-five million square miles of leaf surface are daily engaged in this miracle of photosynthesis, producing oxygen and food for man and beast.

Of the 375 billion tons of food we consume each year the bulk comes from plants, which synthesize it out of air and soil with the help of sunlight. The remainder comes from animal products, which in turn are derived from plants. All the food, drink, intoxicants, drugs and medicines that keep man alive and, if properly used, radiantly healthy are ours through the sweetness of photosynthesis. Sugar produces all our starches, fats, oils, waxes, cellulose. From crib to coffin, man relies on cellulose as the basis for his shelter, clothing, fuel, fibres, basketry, cordage, musical instruments, and the paper on which he scribbles his philosophy.

The abundance of plants profitably used by man is indicated by nearly six hundred pages in Uphof's *Dictionary of Economic Plants*. Agriculture—as the economists agree—is the basis for a nation's wealth.

Instinctively aware of the aesthetic vibrations of plants, which are spiritually satisfying, human beings are happiest and most comfortable when living with flora. At birth, marriage, death, blossoms are prerequisites, as they are at mealtime or festivities. We give plants and flowers as tokens of love, of friendship, or homage, and of thanks for hospitality. Our houses are adorned with gardens, our cities with parks, our nations with national preserves. The first thing a woman does to make a room liveable is to place a plant in it or a vase of fresh cut flowers. Most men, if pressed, might describe paradise, whether in heaven or on earth, as a garden filled with luxuriant orchids, uncut, frequently by a nymph or two.

Aristotle's dogma that plants have souls but no sensation lasted through the Middle Ages and into the eighteenth century, when Carl von Linne, grandfather of modern botany, declared that plants differ from animals and humans only in their lack of movement, a conceit which was shot down by the great nineteenth-century botanist Charles Darwin, who proved that every tendril has its power of independent movement. As Darwin put it, plants "acquire and display this power only when it is of some advantage to them".

At the beginning of the twentieth century a gifted Viennese biologist with the Gallic name of Raoul Francé put forth the idea, shocking to contemporary natural philosophers, that plants move their bodies as freely, and gracefully, as the most skilled animal or human, and that the only reason we don't appreciate the fact is that plants do so at a much slower pace than humans.

The roots of plants, said Francé, burrow inquiringly into the earth, the buds and twigs swing in definite circles, the leaves and blossoms bend and shiver with change, the tendrils circle questingly and reach out with ghostly arms to feel their surroundings. Man, said Francé, merely thinks plants motionless and feelingless because he will not take the time to watch them.

Poets and philosophers such as Johann Wolfgang von Goethe and Rudolf Steiner, who took the trouble to watch plants, discovered that they grow in opposite directions, partly burrowing into the ground as if attracted by gravity, partly shooting up into the air as if pulled by some form of antigravity, or levity.

Wormlike rootlets, which Darwin likened to a brain, burrow constantly downward with thin white threads, crowding themselves firmly into the soil, tasting it as they go. Small hollow chambers in which a ball of starch can rattle indicate to the root tips the direction of the pull of gravity.

When the earth is dry, the roots turn towards moister ground, finding their way into buried pipes, stretching, as in the case of the lowly alfalfa plant, as far as forty feet, developing an energy that can bore through concrete. No one has yet counted the roots of a tree, but a study of a single rye plant indicates a total of over thirteen million rootlets with a combined length of 380 miles. On these rootlets of a rye plant are fine root hairs estimated to number some fourteen billion with a total length of 6,600 miles, almost the distance from pole to pole.

As the special burrowing cells are worn out by contact with stones, pebbles, and large grains of sand, they are rapidly replaced, but when they reach a source of nourishment they die and are replaced by cells designed to dissolve mineral salts and collect the resulting elements. This basic nourishment is passed from cell to cell up through the plant, which constitutes a single unit of protoplasm, a watery or gelatinous substance considered the basis of physical life.

The root is thus a waterpump, with water acting as a universal solvent, raising elements from root to leaf, evaporating and falling back to earth to act once more as the medium for this chain of life. The leaves of an ordinary sunflower will transpire in a day as much water as a man perspires. On a hot day a single birch can absorb as much as four hundred quarts, exuding cooling moisture through its leaves.

No plant, says Francé, is without movement, all growth is a series of movements; plants are constantly preoccupied with bending, turning and quivering. He describes a summer day with thousands of polyplike arms reaching from a peaceful arbor, trembling, quivering in their eagerness for new support for the heavy stalk that grows behind them. When the tendril, which sweeps a full circle in sixty-seven minutes, finds a perch, within twenty seconds it starts to curve around the object, and within the hour has wound itself so firmly it is hard to tear away. The tendril then curls itself like a corkscrew and in so doing raises the vine to itself.

A climbing plant which needs a prop will creep towards the nearest support. Should this be shifted, the vine, within a few hours, will change its course into the new direction. Can the plant see the pole? Does it sense it in some unfathomed way? If a plant is growing between obstructions and cannot see a potential support it will unerringly grow towards a hidden support, avoiding the area where none exists.

Plants, says Francé, are capable of *intent*: they can stretch towards, or seek out, what they want in ways as mysterious as the most fantastic creations of romance.

Far from existing inertly, the inhabitants of the pasture—or what the ancient Hellenes called *botane*—appear to be able to perceive and to react to what is happening in their environment at a level of sophistication far surpassing that of humans.

The sundew plant will grasp at a fly with infallible accuracy, moving in just the right direction towards where the prey is to be found. Some parasitical plants can recognize the slightest trace of the odour of their victim, and will overcome all obstacles to crawl in its direction.

Plants seem to know which ants will steal their nectar, closing when these ants are about, opening only when there is enough dew on their stems to keep the ants from climbing. The more sophisticated acacia actually enlists the protective services of certain ants which it rewards with nectar in return for the ants' protection against other insects and herbivorous mammals.

Is it chance that plants grow into special shapes to adapt to the idiosyncrasies of insects which will pollinate them, luring these insects with special colour and fragrance, rewarding them with their favourite nectar, devising extraordinary canals and floral machinery with which to ensnare a bee so as to release it through a trap door only when the pollination process is completed?

Is it really nothing but a reflex or coincidence that a plant such as the orchid *Trichoceros parviflorus* will grow its petals to imitate the female of a species of fly so exactly that the male attempts to

mate with it and in so doing pollinates the orchid? Is it pure chance that night-blossoming flowers grow white the better to attract night moths and night-flying butterflies, emitting a stronger fragrance at dusk, or that the carrion lily develops the smell of rotting meat in areas where only flies abound, whereas flowers which rely on the wind to crosspollinate the species do not waste energy on making themselves beautiful, fragrant or appealing to insects, but remain relatively unattractive?

To protect themselves plants develop thorns, a bitter taste, or gummy secretions that catch and kill unfriendly insects. The timorous *Mimosa pudica* has a mechanism which reacts whenever a beetle or an ant or a worm crawls up its stem towards its delicate leaves: as the intruder touches a spur the stem raises, the leaves fold up, and the assailant is either rolled off the branch by the unexpected movement or is obliged to draw back in fright.

Some plants, unable to find nitrogen in swampy land, obtain it by devouring living creatures. There are more than five hundred varieties of carnivorous plants, eating any kind of meat from insect to beef, using endlessly cunning methods to capture their prey, from tentacles to sticky hairs to funnel-like traps. The tentacles of carnivorous plants are not only mouths but stomachs raised on poles with which to seize and eat their prey, to digest both meat and blood, and leave nothing but a skeleton.

Insect-devouring sundews pay no attention to pebbles, bits of metal, or other foreign substances placed on their leaves, but are quick to sense the nourishment to be derived from a piece of meat. Darwin found that the sundew can be excited when a piece of thread is laid on it weighing no more than 1/78,000 of a grain. A tendril, which next to the rootlets constitutes the most sensitive portion of a plant, will bend if a piece of silk thread is laid across it weighing but .00025 of a gramme.

The ingenuity of plants in devising forms of construction far exceeds that of human engineers. Man-made structures cannot match the supple strength of the long hollow tubes that support fantastic weights against terrific storms. A plant's use of fibres wrapped in spirals is a mechanism of great resistance against tearing not yet developed by human ingenuity. Cells elongate into sausages or flat ribbons locked one to the other to form almost unbreakable cords. As a tree grows upward it scientifically thickens to support the greater weight.

The Australian eucalyptus can raise its head on a slim trunk above the ground 480 feet, or as high as the Great Pyramid of Cheops, and certain walnuts can hold a harvest of 100,000 nuts. The Virginia knotweed can tie a sailor's knot which is put to such a

strain when it dries that it snaps, hurling the seeds to germinate as far as possible from mother.

Plants are even sentient to orientation and to the future. Frontiersmen and hunters in the prairies of the Mississippi Valley discovered a sunflower plant, *Silphium laciniatum*, whose leaves accurately indicate the points of the compass. Indian liquorice, or *Arbrus precatorius*, is so keenly sensitive to all forms of electrical and magnetic influences it is used as a weather plant. Botanists who first experimented with it in London's Kew Gardens found in it a means for predicting cyclones, hurricanes, tornadoes, earthquakes and volcanic eruptions.

So accurate are alpine flowers about the seasons, they know when spring is coming and bore their way up through lingering snowbanks, developing their own heat with which to melt the Snow.

Plants which react so certainly, so variously, and so promptly to the outer world, must, says Francé, have some means of communicating with the outer world, something comparable or superior to our senses. Francé insists that plants are constantly observing and recording events and phenomena of which man—trapped in his anthropocentric view of the world, subjectively revealed to him through his five senses—knows nothing.

Whereas plants have been almost universally looked upon as senseless automata, they have now been found to be able to distinguish between sounds inaudible to the human ear and colour wavelengths such as infra-red and ultra-violet invisible to the human eye; they are specially sensitive to X-rays and to the high frequency of television.

The whole vegetal world, says Francé, lives responsive to the movement of the earth and its satellite moon, to the movement of the other planets of our solar system, and one day will be shown to be affected by the stars and other cosmic bodies in the universe.

As the external form of a plant is kept a unit and restored whenever part of it is destroyed, Francé assumes there must be some conscious entity supervising the entire form, some intelligence directing the plant, either from within, or from without.

Over half a century ago Francé, who believed plants to be possessed of all the attributes of living creatures including "the most violent reaction against abuse and the most ardent gratitude for favours", could have written a *Secret Life of Plants*, but what he had already put into print was either ignored by the establishment or considered heretically shocking. What shocked them most was his suggestion that the awareness of plants might originate in a supramaterial world of cosmic beings to which, long before the birth of Christ, the Hindu sages referred as "devas", and which, as fairies,

elves, gnomes, sylphs and a host of other creatures, were a matter of direct vision and experience to clairvoyants among the Celts and other sensitives. The idea was considered by vegetal scientists to be as charmingly jejune as it was hopelessly romantic.

It has taken the startling discoveries of several scientific minds in the 1960s to bring the plant world sharply back to the attention of mankind. Even so there are sceptics who find it hard to believe that plants may at last be the bridesmaids at a marriage of physics and metaphysics.

Evidence now supports the vision of the poet and the philosopher that plants are living, breathing, communicating creatures, endowed with personality and the attributes of soul. It is only we, in our blindness, who have insisted on considering them automata. Most extraordinary, it now appears that plants may be ready, willing, and able to cooperate with humanity in the Herculean job of turning this planet back into a garden from the squalor and corruption of what England's pioneer ecologist William Cobbett would have called a "wen". (Taken from *The Secret Life of Plants*. 1973. pp.7-13).

The Way Nature Farms

By Sir Albert Howard

Little or no consideration is paid in the literature of agriculture to the means by which Nature manages land and conducts her water culture. Nevertheless, these natural methods of soil management must form the basis of all our studies of soil fertility.

What are the main principles underlying Nature's agriculture? These can most easily be seen in operation in our woods and forests.

Mixed farming is the rule: plants are always found with animals: many species of plants and of animals all live together. In the forest every form of animal life, from mammals to the simplest invertebrates, occurs. The vegetable kingdom exhibits a similar range: there is never any attempt at monoculture: mixed crops and mixed farming are the rule.

The soil is always protected from the direct action of sun, rain, and wind. In this care of the soil strict economy is the watchword: nothing is lost. The whole of the energy of sunlight is made use of by the foliage of the forest canopy and of the undergrowth. The leaves also break up the rainfall into fine spray so that it can the more easily be dealt with by the litter of plant and animal remains which

provide the last line of defence of the precious soil. These methods of protection, so effective in dealing with sun and rain, also reduce the power of the strongest winds to a gentle air current.

The rainfall in particular is carefully conserved. A large portion is retained in the surface soil: the excess is gently transferred to the subsoil and in due course to the streams and rivers. The fine spray created by the foliage is transformed by the protective ground litter into thin films of water which move slowly downwards, first into the humus layer and then into the soil and subsoil. These latter have been made porous in two ways: by the creation of a well-marked crumb structure and by a network of drainage and aeration channels made by earthworms and other burrowing animals. The pore space of the forest soil is at its maximum so that there is a large internal soil surface over which the thin films of water can creep. There is also ample humus for the direct absorption of moisture. The excess drains away slowly by way of the subsoil. There is remarkably little run-off, even from the primeval rainforest. When this occurs it is practically clear water. Hardly any soil is removed. Nothing in the nature of soil erosion occurs. The streams and rivers in forest areas are always perennial because of the vast quantity of water in slow transit between the rainstorms and the sea. There is therefore little or no drought in forest areas because so much of the rainfall is retained exactly where it is needed. There is no waste anywhere.

The forest manures itself. It makes its own humus and supplies itself with minerals. If we watch a piece of woodland we find that a gentle accumulation of mixed vegetable and animal residues is constantly taking place on the ground and that these wastes are being converted by fungi and bacteria into humus. The processes involved in the early stages of this transformation depend throughout on oxidation: afterwards they take place in the absence of air. They are sanitary. There is no nuisance of any kind—no smell, no flies, no dustbins, no incinerators, no artificial sewage system, no water-borne diseases, no town councils, and no rates. On the contrary, the forest affords a place for the ideal summer holiday: sufficient shade and an abundance of pure fresh air. Nevertheless, all over the surface of the woods the conversion of vegetable and animal wastes into humus is never so rapid and so intense as during the holiday months—July to September.

The mineral matter needed by the trees and the undergrowth is obtained from the subsoil. This is collected in dilute solution in water by the deeper roots, which also help in anchoring the trees. Even in soils markedly deficient in phosphorus, trees have no difficulty in obtaining ample supplies of this element. Potash, phosphate, and other minerals are always collected in situ and carried by the transpiration current for use in the green leaves. Afterwards they are

either used in growth or deposited on the floor of the forest in the form of vegetable waste—one of the constituents needed in the synthesis of humus. This humus is again utilized by the roots of the trees. Nature's farming, as seen in the forest, is characterized by two things: (1) a constant circulation of the mineral matter absorbed by the trees; (2) a constant addition of new mineral matter from the vast reserves held in the subsoil. There is therefore no need to add phosphates: there is no necessity for more potash salts. No mineral deficiencies of any kind occur. The supply of all the manure needed is automatic and is provided either by humus or by the soil. There is a natural division of the subject into organic and inorganic. Humus provides the organic manure; the soil the mineral matter.

The soil always carries a large fertility reserve. There is no hand to mouth existence about Nature's farming. The reserves are carried in the upper layers of the soil in the form of humus. Yet any useless accumulation of humus is avoided because it is automatically mingled with the upper soil by the activities of burrowing animals such as earthworms and insects. The extent of this enormous reserve is only realized when the trees are cut down and the virgin land is used for agriculture. When plants like tea, coffee, rubber, and bananas are grown on recently cleared land, good crops can be raised without manure for ten years or more. Like all good administrators, therefore, Nature carries strong liquid reserves effectively invested. There is no squandering of these reserves to be seen anywhere.

The crops and livestock look after themselves. Nature has never found it necessary to design the equivalent of the spraying machine and the poison spray for the control of insect and fungous pests. There is nothing in the nature of vaccines and serums for the protection of the livestock. It is true that all kinds of diseases are to be found here and there among the plants and animals of the forest, but these never assume large proportions. The principle followed is that the plants and animals can very well protect themselves even when such things as parasites are to be found in their midst. Nature's rule in these matters is to live and let live.

If we study the prairie and the ocean we find that similar principles are followed. The grass carpet deals with the rainfall very much as the forest does. There is little or no soil erosion: the run-off is practically clear water. Humus is again stored in the upper soil. The best of the grassland areas of North America carried a mixed herbage which maintained vast herds of bison. No veterinary service was in existence for keeping these animals alive. When brought into cultivation by the early settlers, so great was the store of fertility that these prairie soils yielded heavy crops of wheat for many years without livestock and without manure.

In lakes, rivers, and the sea mixed farming is again the rule: a

great variety of plants and animals are found living together: nowhere does one find monoculture. The vegetable and animal wastes are again dealt with by effective methods. Nothing is wasted. Humus again plays an important part and is found everywhere in solution, in suspension, an in the deposits of mud. The sea, like the forest and the prairie, manures itself.

The main characteristic of Nature's farming can therefore be summed up in a few words. Mother earth never attempts to farm without livestock; she always raises mixed crops; great pains are taken to preserve the soil and to prevent erosion; the mixed vegetable and animal wastes are converted into humus; there is no waste; the processes of growth and the processes of decay balance one another; ample provision is made to maintain large reserves of fertility; the greatest care is taken to store the rainfall; both plants and animals are left to protect themselves against disease. (Taken from *An Agricultural Testament*. 1995. pp.1-4).

Natural Farming

By Masanobu Fukuoka

Natural farming is a method that actually goes a step beyond science. The proof is that over these past twenty years I have not read a single book on the topic, and yet have managed to stay at the forefront of rice cultivation practices in Japan. Try comparing the findings that I reported ten years ago with what agricultural testing centers have been doing thereafter and you'll see that most prefectural centers are now doing what one lone farmer tried a decade ago. And they're arriving at the same conclusions—but, of course, ten years after me.

My purpose here is not to boast. I would simply like you to know that I walk always the shortest road. By this I mean that my teacher is nature itself. Nature is always perfect in every case. I have had a good teacher. Other people have broken nature down and looked at it only as small fragments, so what they learn is incomplete. Because they have a bad teacher, despite their diligent studying and application, they reap little from their efforts. Science never does any more than mimic a virtual image of nature that exists only in the human mind, so what it grasps is only an incomplete and inferior imitation of the real thing. I can assert here without the least doubt that anything created by man with scientific knowledge will always be inferior to nature. When one realizes just how wondrous a thing

nature is, one can only bow to it in humble acknowledgment. The moment that we become humble before nature and renounce the self, the self shall become assimilated into nature and nature shall allow it to live. Even a small ego becomes capable of summoning great strength. It is enough merely to know this road and walk it each day. (Taken from *The Road Back to Nature*, pp.223-224)

Although I have already shown in some detail the differences between natural farming and scientific farming, I would like to return here to compare the principles on which each is based. For the sake of convenience, I shall divide natural farming into two types and consider each separately.

Mahayana Natural Farming: When the human spirit and human life blend with the natural order and man devotes himself entirely to the service of nature, he lives freely as an integral part of the natural world, subsisting on its bounty without having to resort to purposeful effort. This type of farming, which I shall call Mahayana natural farming, is realized when man becomes one with nature, for it is a way of farming that transcends time and space and reaches the zenith of understanding and enlightenment.

This relationship between man and nature is like an ideal marriage in which the partners together realize a perfect life without asking for, giving, or receiving anything of each other. Mahayana farming is the very embodiment of life in accordance with nature. Those who live such a life are hermits and wise men.

Hinayana Natural Farming: This type of farming arises when man earnestly seeks entry to the realm of Mahayana farming. Desirous of the true blessings and bounty of nature, he prepares himself to receive it. This is the road leading directly to complete enlightenment, but is short of that perfect state. The relationship between man and nature here is like that of a lover who yearns after his loved one and asks for her hand, but has not realized full union.

Scientific Farming: Man exists in a state of contradiction in which he is basically estranged from nature, living in a totally artificial world, yet longs for a return to nature. A product of this condition, scientific farming forever wanders blindly back and forth, now calling upon the blessings of nature, now rejecting it in favor of human knowledge and action. Returning to the same analogy, our lover here is unable to decide whose hand to ask in marriage, and, while agonizing over his indecision, imprudently courts the ladies, heedless of social proprieties.

The Three Ways of Farming Compared

1. *Mahayana natural farming*: This and scientific farming are on entirely different planes. Although it is a bit strange to directly compare the two and discuss their relative merits, the only way we have of expressing their value in this world of ours is by comparison and contrast. Scientific agriculture draws as much as it can from natural forces and attempts, by adding human knowledge, to produce results that eclipse nature. Naturally, proponents of this type of farming think it superior to natural farming, which relies entirely on the forces and resources of nature.

Philosophically, however, scientific farming cannot be superior to Mahayana natural farming because, while scientific farming is the sum of knowledge and forces extracted from nature by the human intellect, this still amounts to finite human knowledge. No matter how one totals it up, human knowledge is but a tiny, closely circumscribed fraction of the infinitude of the natural world. In contrast to the vast, boundless, perfect knowledge and power of nature, the finite knowledge of man is always limited to small pockets of time and space. Inherently imperfect as it is, human knowledge can never be collected together to form perfect knowledge.

As imperfection can never be the equal of perfection, so scientific farming must always yield a step to Mahayana natural farming. Nature encompasses everything. No matter how desperately he struggles, man will never be more than a small, imperfect part of its totality. Clearly then, scientific farming, which is inherently incomplete, can never hope to attain the immutable absoluteness of natural farming.

2. *Hinayana natural farming*: This type of farming belongs in the same world of relativity as scientific farming, and so the two may be directly compared. Both are alike in that they are derived from that nature which is verified with discriminating knowledge. But Hinayana farming attempts to cast off human knowledge and action and devote itself to making the greatest possible use of the pure forces of nature, whereas scientific farming uses the powers of nature and adds human knowledge and action in an effort to establish a superior way of farming.

The two differ fundamentally and are diametrically opposed in their perceptions, thinking, and the direction of research, but to explain the methods of Hinayana farming we have no choice but to borrow the terms and methods of science. So for the sake of simplicity, we shall place it temporarily in the realm of science.

In this respect, it resembles the position of the Eastern arts of healing vis-a-vis Western medicine. The direction in which Hinayana

natural farming points leads beyond the world of science and to a rejection of scientific thinking.

This view is based on the philosophical conviction that if man makes a genuine effort to approach nature, then even should he abandon all deeds and actions, nature will take each of these over and perform them for him.

3. *Scientific farming*: Pure natural farming should therefore be judged on philosophical grounds, while scientific farming should be evaluated on scientific grounds. Because scientific farming is limited to immediate circumstances in every respect, its achievements may excel in a restricted sense but are invariably inferior in all other ways. In contrast, natural farming is total and comprehensive, so its achievements must be judged from a broad, universal perspective.

When scientific methods are used to grow a fruit tree, for example, the goal may be to produce large fruit, in which case all efforts will be concentrated to this end. Yet all that will be achieved is the production of what may, in a limited sense, be regarded as large fruit. The fruit produced by scientific farming is always large—even unnaturally so—in a relative sense, but invariably has grave flaws. Essentially, what is being grown is deformed fruit. To determine the true merit of scientific farming, one has to decide whether producing large fruit is truly good for man. The answer to this should be obvious.

Scientific farming constantly practices the unnatural without the slightest concern, but this is of very great significance and invites the gravest of consequences. The unnaturalness of scientific farming leads directly to incompleteness, which is why its results are always distorted and at best of only local utility. (Taken from *The Natural Way of Farming*. pp 93-95).

"Do-Nothing" Farming

The method of "do-nothing" farming is based on four major principles:

1. No cultivation
2. No fertilizer
3. No weeding
4. No pesticides

No Cultivation

Plowing a field is hard work for the farmer and usually one of the most important activities in farming operations. In fact, to many

people, being a farmer is synonymous with turning the soil with plow or hoe. If working the soil is unnecessary then, the image and reality of the farmer change drastically. Let us look at why plowing is thought to be essential and what effect it actually has.

Plowing Ruins the Soil: Knowing that the roots of crops penetrate deep into the earth in search of air, water, and nutrients, people reason that making larger amounts of these ingredients available to the plants will speed crop growth. So they clear the field of weeds and turn the soil from time to time, believing that this loosens and aerates the soil, increases the amount of available nitrogen by encouraging nitrification, and introduces fertilizer into the soil where it can be absorbed by the crops.

Of course, plowing under chemical fertilizers scattered over the surface of a field will probably increase fertilizer effectiveness. But this is true only for cleanly plowed and weeded fields on which fertilizer is applied. Grassed fields and no-fertilizer cultivation are a different matter altogether. We therefore have to examine the necessity of plowing from a different perspective. As for the argument that this helps increase available nitrogen through nitrification, this is analogous to wasting one's body for some temporary gain.

Plowing is supposed to loosen the soil and improve the penetration of air, but does not this in fact have the opposite effect of compacting the soil and decreasing air porosity? When a farmer plows his fields and turns the soil with a hoe, this appears to create air spaces in the soil and soften the dirt. But the effect is the same as kneading bread: by turning the soil, the farmer breaks it up into smaller and smaller particles which acquire an increasingly regular physical arrangement with smaller interstitial spaces. The result is a harder, denser soil.

The only effective way to soften up the soil is to apply compost and work it into the ground by plowing. But this is just a short-lived measure. In fields that have been weeded clean and carefully plowed and re-plowed, the natural aggregation of the soil into larger particles is disturbed; soil particles become finer and finer, hardening the ground.

Wet paddy fields are normally supposed to be tilled five, six, or even seven times during the growing season. The more zealous farmers have even competed with each other to increase the number of plowings. Everyone thought this softened the soil in the paddy and let more air into the soil. That is the way it looked to most people for a long time, until after World War II, when herbicides became available. Then farmers discovered that when they sprayed their fields with herbicides and reduced the frequency of plowing, their yields improved. This demonstrated that intertillage had been effec-

tive as a weeding process but had been worthless as a means for loosening the soil.

To say that tilling the soil is worthless is not the same as claiming that it is unnecessary to loosen the soil and increase its porosity. No, in fact I would like to stress, more than anyone else, just how important an abundance of air and water are to the soil. It is in the nature of soil to swell and grow more porous with each passing year. This is absolutely essential for microorganisms to multiply in the earth, for the soil to grow more fertile, and for the roots of large trees to penetrate deep into the ground. Only I believe that, far from being the answer, working the soil with plow and hoe actually interferes with these processes. If man leaves the soil to itself, the forces of nature will enrich and loosen.

Farmers usually plow the soil to a depth of about four to eight inches, whereas the roots of grasses and green manure crops work the soil down to twelve inches, fifteen inches, or more. When these roots reach down deep into the earth, air and water penetrate into the soil together with the roots. As these wither and die, many types of microorganisms proliferate. These organisms die and are replaced by others, increasing the amount of humus and softening the soil. Earthworms eventually appear where there is humus, and as the number of earthworms increases, moles begin burrowing through the soil.

The Soil Works Itself: The soil lives of its own accord and plows itself. It needs no help from man. Farmers often talk of "taming the soil" and of a field becoming "mature", but why is it that trees in mountain forests grow to such magnificent heights without the benefit of hoe or fertilizer, while the farmer's fields can grow only puny crops?

Has the farmer ever given any careful thought to what plowing is? Has he not trained all his attention on a thin surface layer and neglected to consider what lies below that?

Trees seem to grow almost haphazardly in the mountains and forests, but the cedar grows where it can thrive to its great size, mixed woods rise up where mixed woods must, and pine trees germinate and grow in places suited for pine trees. One does not see pines growing at the bottom of a valley or cedar seedlings taking root on mountain tops. One type of fern grows on infertile land and another in areas of deep soil. Plants that normally grow along the water's edge are not found on mountain tops, and terrestrial plants do not thrive in the water. Although apparently without intent or purpose, these plants know exactly where they can and should grow.

Man talks of "the right crop for the right land," and does studies to determine which crops grow well where. Yet research has hardly

touched upon such topics as the type of parent rock and soil structure suited to mandarin orange trees, or the physical, chemical, and biological soil structures in which persimmon trees grow well. People plant trees and sow seed without having the faintest idea of what the parent rock on their land is and without knowing anything about the structure of the soil. It is no wonder then that farmers worry about how their crops are going to turn out.

In the mountain forests, however, concerns over the physical and chemical compositions of the topsoil and deeper strata are nonexistent; without the least help from man, nature creates the soil conditions sufficient to support dense stands of towering trees. In nature, the very grasses and trees, and the earthworms and moles in the ground, have acted the part of plowhorse and oxen, completely rearranging and renewing the soil. What can be more desirable to the farmer than being able to work the fields without pulling a plow or swinging a hoe? Let the grasses plow the topsoil and the trees work the deeper layers. Everywhere I look, I am reminded of how much wiser it is to entrust soil improvement to the soil and plant growth to the inherent powers of plants.

There is no need to plow or improve a soil because nature has been working at it with its own methods for thousands of years. Man has restrained the hand of nature and taken up the plow himself. But this is just man imitating nature. All he has really gained from this is a mastery at scientific exposition.

No amount of research can teach man everything there is to know about the soil, and he will certainly never create soils more perfect than those of nature. Because nature itself is perfect. If anything, advances in scientific research teach man just how perfect and complete a handful of soil is, and how incomplete human knowledge.

We can either choose to see the soil as imperfect and take hoe in hand, or trust the soil and leave the business of working it to nature.

No Fertilizer

Crops Depend on the Soil: When we look directly at how and why crops grow on the earth, we realize that they do so independently of human knowledge and action. This means that they have no need basically for such things as fertilizers and nutrients. Crops depend on the soil for growth.

I have experimented with fruit trees and with rice and winter grain to determine whether these can be cultivated without fertilizers. Of course crops can be grown without fertilizer. Nor does this yield the poor harvests people generally believe. In fact, I have been

able to show that by taking full advantage of the inherent powers of nature, one can obtain yields equal to those that can be had with heavy fertilization. But before getting into a discussion of why it is possible to farm without using fertilizers and whether the results are good or bad, I would like to look first at the road scientific farming has taken.

Long ago, people saw crops growing in the wild and called this "growth". Applying discriminating knowledge, they proceeded from the notion of wild plant growth to plant cultivation.

For example, scientists typically begin by analyzing rice and barley plants and identifying the various nutrients. They then speculate that these nutrients promote the growth of rice and barley. Next they apply the nutrients as fertilizer, and observing that the plants grow as expected, they conclude that the fertilizer is what makes the crops grow. The moment they compare crops grown with and without fertilizer and conclude that fertilizer application results in taller, better yielding plants, people cease to doubt the value of fertilizers.

Are Fertilizers Really Necessary? The Same is true when one delves into the reasons why fertilizers are thought to be essential to fruit trees. Pomologists normally begin with an analysis of the trunk, leaves, and fruit of the tree. From this they learn what the nitrogen, phosphorus, and potassium contents are and how much of these components are consumed per unit of annual growth or of fruit produced. Based on the results of such analyses, fertilization schedules for fruit trees in mature orchards will typically set the amount of nitrogen components at 90 pounds, say, and the amount of phosphates and potassium at 70 pounds each. Researchers will apply fertilizer to trees grown in test plots or earthen pots, and examining the growth of the tree and the amount and quality of fruit it bears, will claim to have demonstrated the indispensability of fertilizer.

Learning that nitrogenous components are present in the leaves and branches of citrus trees and that these are absorbed from the ground by the roots, man hits upon the idea of administering fertilizer as a nutrient source. If this succeeds in supplying the nutrient needs of the leaves and branches, man immediately jumps to the conclusion that applying fertilizer to citrus trees is both necessary and effective.

If one works from the assumption that fruit trees must "be grown", the absorption of fertilizer by the roots becomes the cause, and the full growth of the leaves and branches the effect. This leads quite naturally to the conclusion that applying fertilizer is necessary.

However, if we take as our starting point the view that a tree grows of its own accord, the uptake of nutrients by the tree's roots is

no longer a cause but, in the eyes of nature, just a small effect. One could say that the tree grew as a result of the absorption of nutrients by the roots, but one could also claim that the absorption of nutrients was caused by something else, which had the effect of making the tree grow. The buds on a tree are made for budding and so this is what they do; the roots, with their powers of elongation, spread and extend throughout the earth. A tree has a shape perfectly adapted to the natural environment. With this, it guards the providence of nature and obeys nature's laws, growing neither too fast nor too slow, but in total harmony with the great cycles of nature.

The Countless Evils of Fertilizer: What happens when the farmer arrives in the middle of all this and spreads his fields and orchards with fertilizer? Dazzled and led astray by the rapid growth he hears of, he applies fertilizer to his trees without giving any thought to the influence this has on the natural order.

As long as he cannot know what effects scattering a handful of fertilizer has on the natural world, man is not qualified to speak of the effectiveness of fertilizer application. Determining whether fertilizer does a tree or soil good or harm is not something that can be decided overnight.

The more scientists learn, the more they realize just how awesome is the complexity and mystery of nature. They find this to be a world filled with boundless, inscrutable riddles. The amount of research material that lies hidden in a single gram of soil, a single particle, is mind-boggling.

People call the soil mineral matter, but some one hundred million bacteria, yeasts, molds, diatoms, and other microbes live in just one gram of ordinary topsoil. Far from being dead and inanimate, the soil is teeming with life. These microorganisms do not exist without reason. Each lives for a purpose, struggling, cooperating, and carrying on the cycles of nature.

Into this soil, man throws powerful chemical fertilizers. It would take years of research to determine how the fertilizer components combine and react with air, water, and many other substances in nonliving mineral matter, what changes they undergo, and what relationships should be maintained between these components and the various microorganisms in order to guard a harmonious balance.

Very little, if any, research has been done yet on the relationship between fertilizers and soil microbes. In fact, most experiments totally ignore this. At agricultural research stations, scientists place soil in pots and run tests, but more likely as not, most of the soil microbes in these pots die off. Clearly, results obtained from tests conducted under fixed conditions and within a limited experimental framework cannot be applied to situations under natural conditions.

Yet, just because a fertilizer slightly accelerates crop growth in such tests, it is praised lavishly and widely reported to be effective. Only the efficacy of the fertilizer is stressed; almost nothing is said about its adverse effects, which are innumerable. (pp.103-109)

No-fertilizer natural farming essentially means the natural cultivation of crops without fertilizers in a soil and environment under totally natural conditions. By totally natural cultivation I mean no-fertilizer tests under "condition-less" conditions. However such experiments are out of the reach of scientists, and indeed impossible to perform. I am convinced that cultivation without fertilizers under natural circumstances is not only philosophically feasible, but is more beneficial than scientific, fertilizer-based agriculture, and preferable for the farmer. Yet, although cultivation without the use of chemical fertilizers is possible, crops cannot immediately be grown successfully without fertilizers on fields that are normally plowed and weeded.

It is imperative that farmers think seriously about what nature is and provide a growing environment that approaches at least one step closer to nature. But to farm in nature, one must first make an effort to return to that natural state which preceded the development of the farming methods used by man.

Take a Good Look at Nature: When trying to determine whether crops can be grown without fertilizers, one cannot tell anything by examining only the crops. One must begin by taking a good look at nature.

The trees of the mountain forests grow under nearly natural conditions. Although they receive no fertilizer by the hand of man, they grow very well year after year. Reforested cedars in a favorable area generally grow about forty tons per quarter-acre over a period of twenty years. These trees thus produce some two tons of new growth each year without fertilizer. This includes only that part of the tree that can be used as lumber, so if we take into account also small branches, leaves, and roots, then annual production is probably closer to double, or about four tons.

In the case of a fruit orchard, this would translate into two to four tons of fruit produced each year without fertilizers—about equal to standard production levels by fruit growers today.

After a certain period of time, the trees in a timber stand are felled, and the entire surface portion of the tree—including the branches, leaves, and trunk—is carried away. So not only are fertilizers not used, this is slash-and-burn agriculture. How then, and from where, are the fertilizer components for this production volume supplied each year to the growing trees? Plants do not need to be raised; they grow of their own accord. The mountain forests are living proof that trees are not raised with fertilizer but grow by themselves. (pp.109-110)

Nature is not dead. It lives and it grows. All that man has to do is direct these vast hidden forces to the growth of fruit trees, But rather than using this great power, people choose to destroy it. Weeding and plowing the fields each year depletes the fertility of the soil, creates a deficiency of trace components, diminishes the soil's vitality, hardens the topsoil, kills off microbes, and turns rich, living, organic material into a dead, inanimate, yellowish-white mineral matter the only function of which is to physically support the crops. (p.111)

No Weeding

Nothing would be more welcome to the farmer than not having to weed his fields, for this is his greatest source of toil. Not having to weed or plow might sound like asking for too much, but if one stops to think about what repeatedly weeding and running a plow through a field actually means, it becomes clear that weeding is not as indispensable as we have been led to believe.

Is There Such a Thing as a Weed?: Does no one question the common view that weeds are a nuisance and harmful to the raising of crops?

The first step that those who distinguish between crops and weeds take is to decide whether to weed or not to weed. Like the many different microorganisms that struggle and cooperate in the soil, myriad grasses and trees live together on the soil surface. Is it right then to destroy this natural state, to pick out certain plants living in harmony among many plants and call these "crops", and to uproot all the others as "weeds"?

In nature, plants live and thrive together. But man sees things differently. He sees coexistence as competition; he thinks of one plant as hindering the growth of another and believes that to raise a crop, he must remove other grasses and herbs. Had man looked squarely at nature and placed his trust in its powers, would he not have raised crops in harmony with other plants? Ever since he chose to differentiate crop plants from other plants, he has felt compelled to raise crops through his own efforts. When man decides to raise one crop, the attention and devotion he focuses on raising that crop gives birth to a complementary sense of repulsion and hate that excludes all else.

The moment that the farmer started caring for and raising crops, he began to regard other herbs with disgust as weeds and has striven ever since to remove them. But because the growth of weeds is natural, there is no end to their variety or to the labors of those who work to remove them.

If one believes that crops grow with the aid of fertilizers, then the surrounding weeds must be removed because they rob the crop plants of fertilizer. But in natural farming, where plants grow of their own accord without relying on fertilizers, the surrounding weeds do not pose any problem at all. Nothing is more natural than to see grass growing at the foot of a tree; no one would ever think of that grass as interfering with the growth of the tree.

In nature, bushes and shrubs grow at the foot of large trees, grasses spread among the shrubs, and mosses flourish beneath the grasses. Instead of cut-throat competition for nutrients, this is a peaceful world of coexistence. Rather than seeing the grasses as stunting shrub growth, and the shrubs as slowing the growth of trees, one should feel instead a sense of wonder and amazement at the ability of these plants to grow together in this way.

Weeds Enrich the Soil: Instead of pulling weeds, people should give some thought to the significance of these plants. Having done so, they will agree that the farmer should let the weeds live and make use of their strength. Although I call this the "no-weeding" principle, it could also be known as the principle of "weed utility".

Long ago, when the earth began to cool and the surface of the earth's crust weathered, forming soil, the first forms of life to appear were bacteria and lower forms of plant life such as algae. All plants arose for a reason, and all plants live and thrive today for a reason. None is useless; each makes its own contribution to the development and enrichment of the biosphere. Such fertile soil would not have formed on the earth's surface had there been no microorganisms in the earth and grasses on, the surface. Grasses and other plants do not grow without a purpose.

The deep penetration of grass roots into the earth loosens the soil. When the roots die, this adds to the humus, allowing soil microbes to proliferate and enrich the soil. Rainwater percolates through the soil and air is carried deep down, supporting earthworms, which eventually attract moles. Weeds and grasses are absolutely essential for a soil to remain organic and alive.

Without grasses growing over the surface of the ground, rainwater would wash away part of the topsoil each year. Even in gently sloping areas, this would result in the loss of from several tons to perhaps well over a hundred tons of soil per year. In twenty to thirty years, the topsoil would wash entirely away, reducing soil fertility to essentially zero. It would make more sense then for farmers to stop pulling weeds and begin making use of their considerable powers.

Of course, it is understandable when farmers say that weeds growing wild in rice and wheat fields or under fruit trees interfere with other work. Even in cases where cultivation with weeds appears

to be possible and even beneficial in principle, monoculture is more convenient for the farmer. This is why, in practice, one must adopt a method that utilizes the strength of weeds but also takes into account the convenience of farming operations—a "weedless" method that allows the weeds to grow. (pp.112-113)

No Pesticides

Insect Pests Do Not Exist: The moment the problem of crop disease or insect damage arises, talk turns immediately to methods of control. But we should begin by examining whether crop disease or insect damage exist in the first place. A thousand plant diseases exist in nature, yet in truth there are none. It is the agricultural specialist who gets carried away with discussions on disease and pest damage. Although research is done on ways to reduce the number of country villages without doctors, no studies are ever run to find out how these villages have managed to get by without doctors. In the same way, when people spot signs of a plant disease or an insect pest, they immediately go about trying to get rid of it. The smart thing to do would be to stop treating insects as pests and find a way that eliminates the need for control measures altogether.

I would like to take a look now at the question of new pesticides, which has escalated into a major pollution problem. The problem exists because, very simply, there are no non-polluting new pesticides.

Most people seem to believe that the use of natural predators and pesticides of low toxicity will clear up the problem, but they are mistaken. Many feel reassured by the thought that the use of beneficial insect predators to control pests is a biological method of control without harmful repercussions, but to someone who understands the chain of being that links together the world of living organisms, there is no way of telling which organisms are beneficial predators and which are pests. By meddling with controls, all man accomplishes is destruction of the natural order. Although he may appear to be protecting the natural enemies and killing the pests, there is no way of knowing whether the pests will become beneficial and the predators pests. Many insects that are harmless in a direct sense are harmful indirectly. And when things get even more complex, as when one beneficial insect feeds on a pest that kills another beneficial insect which feeds on another pest, it is futile to try and draw sharp distinctions between these and apply pesticides selectively. (From *The Natural Way of Farming*, pp. 114-115).

Principles of Organic Farming in the Tropics

By Sailen Ghosh

Organic farming is very much native to this country. Whoever tries to write a history of organic farming will have to refer to India and China. The farmers of these two large countries are known as "farmers of forty centuries" and it is organic farming that sustained them. Therefore, it is not that some ideas about organic farming originated in the West and we are borrowing them. It is our own product, our contribution to the world.

Many people raise disputes about the nomenclature. Some say, "why talk of organic farming? Call it Eco-farming." Some others prefer the term "biological farming". Yet others prefer "bio-dynamic farming", "macro-biotic agriculture", etc. It is not necessary to go into the niceties of these terms and the shades of differences between their emphasis.

The basic point is that we need natural farming because it is farming based on natural principles which alone is sustainable. When farming encompasses all the wholesome natural principles, the total package of products is much more than the sum of yields which would be otherwise available. This is because there are symbiotic effects when these principles are allowed to be in operation together. In their joint harness they become more productive.

The next point to note is that there is a core of commonality between "eco-farming", "bio-dynamic farming", etc. Their common seminal principle is that instead of trying to feed the plant directly, the objective should be to nourish the soil. The proponents of each of these natural forms of farming are convinced that bypassing the question of soil health is as foolish and counterproductive as the attempts of men who seek merely to "fertilise" sick women i.e. to make them produce babies.

Organic farming means farming in the spirit of organic relationship. When you say this, it opens up a whole vista. In nature, organic relationship is a pervasive phenomenon. Everything is connected with everything else. Hence organic farming is not mere non-chemicalism in agriculture. To be able to sustain this "non-chemicalism", it has to get support from a host of other factors which are inseparably connected. Herein lies the essence of organicism.

Since organic farming means placing farming on integral relationship, we have to know the relationship between the soil, water and plants; between soil, soil microbes and waste products; between the vegetable kingdom and the animal kingdom, of which the apex animal is the human being; between agriculture and forestry;

between soil, water and atmosphere, etc. It is the totality of these relationships that is the bedrock of organic farming.

However, the understanding of this totality of relationships in a general way is not sufficient for success in organic farming. Understanding the local specificity in respect of each aspect of these multiple relationships is also important. Much of this understanding is reflected in the traditional practices (folk practices) which developed over centuries. Practices which have been sought to be obliterated by the much vaunted "modernist" practices.

There are yet other questions. Organic farming is linked with the question of organic living. The ideal of organic living is very different from the kind of living being encouraged by the commercial civilisation of today, where you find artificiality in everything—from conduct to food. Genuineness, simplicity, naturalness and harmonious relationship with the people around and with the plant and animal kingdoms will have to be restored.

Why did organic farming, which was so much in vogue in this country, recede here itself in this century? Was it due to any inherent shortcomings or due to something else? According to my analysis the reasons were three:

First, chemicalised farming based on factory made chemicals had a romantic beginning. During the first world war when some German scientists developed a process of making ammonia by combining hydrogen and nitrogen gases under pressure and then converting this ammonia into nitric acid to meet their military needs, we were overwhelmed to see the wonderful effects of modern science. What thrilled us was the ability of this science to come to the rescue of the German state by enabling it to scorn the cessation of supply of sulphate from Chile. We were further dazzled when, after the war, the Germans—and following them, the Europeans—applied this ammonia to increase foodgrain yields. This chemical-oriented technology had the advantage of the time and milieu. It developed at a time when nobody could even imagine that it could have any deleterious effects on soil, water or atmosphere or on the production of other items in the food package. It also grew in an environment where the deleterious show up much more slowly: the decomposition of soil organic matter in temperate climates, is far less than in tropical countries. So it was easy to fall a prey to its charm. Of all political leaders and social thinkers, possibly Mahatma Gandhi was the only one who remained free from this illusion.

Secondly, we in India easily come under a spell of foreign technology. This is because our elite developed an intellectual slavery which continues till today. Seeing the Europeans and North Americans well-fed, well-dressed and equipped with labour-saving gadgets,

we, as a nation, developed an inferiority complex and became imitative in everything, including farming. The leaders who gave direction to the Indian State after Independence, were least informed about farming. Moreover, the fact that both Euro-Americans and their rival, the Russians, accepted chemicalisation of farming, made it appear that this farming technology was so superior as to be beyond dispute.

Thirdly—and this is the most important—we had inherited organic farming as a tradition. Neither our farmers nor our elite were aware of the science on which it was based. So it was easy to discard it as we have discarded certain other traditions which appeared to us as mere prejudices. In this case, the lure of immediate economic gain made the discarding easier. In any case, when the state as a whole pushed hard the ideal of an industrial-commercial civilisation—of course, with an admixture of "cooperative commonwealth" verbiage—organic farming was bound to recede because it was just not compatible with this drive towards commercialism. The plea of feeding an ever-increasing population was used to lull farmers into a false sense of security in chemical-oriented farming.

One important thing which many scientists often underplay or do not realise is the basic difference between the temperate and the tropical climate conditions. It is necessary to understand this difference to know why the USA, Europe and Japan, which are all in temperate climates, have escaped rapid destruction despite chemicalised farming and why the destruction caused by this method of farming is far more rapid in the tropics. In temperate climates, the rainfall is evenly distributed throughout the year. There is neither torrential downpour nor any long dry spell. As against this, in the humid tropical zones, there is torrential rainfall for three or four months, during which there is a heavy run-off of the topsoil unless there is protective forest cover. This is followed by a long dry spell, during which the soil is baked hard and much of it cracks. Hence when the rains next come, this cracked soil washes away at an even greater rate. On the other hand, in the dry tropics, the rainfall is scanty, the particles of scorched soil disintegrate rapidly and the bits are blown off by the wind. Thus, the proneness for soil erosion is much higher in both wet and dry tropics. Besides, high humidity and high temperature cause high bacterial activity in the wet tropics, leading to quick decomposition of soil organic matter and making the soil yet more prone to erosion unless there is continuing replenishment of organic matter. If nitrogenous fertiliser is applied under these conditions, it leads to further oxidation of soil organic matter.

In temperate climates, the soil remains moist throughout the year. Snowfall in winter conserves organic material underneath. The soft flow of molten snow in summer, too, is beneficial to soil: it does

not scour. This is why the organic matter status of soils in temperate countries is very much higher. These have a larger cushion, with a high carbon-to-nitrogen ratio, and hence with a higher capacity for absorption of artificial nitrogen. This is the reason why both the eroding and the polluting effects of chemical fertilisers are much slower and much less visible in temperate countries.

Since the differences between the temperate and the tropical countries are too obvious to be completely ignored, our agricultural science research bosses concede that there are certain differences. But in doing this they give certain twists so as to pipe our science to the tail of "modern" western science, oriented as it is to conquering Nature rather than understanding her ways. Let me give a simple example of this twist. This was, in fact, my first shocking experience with our agricultural science establishment. In 1972, I wrote in a journal, Oil Commentary, then edited by me, an article "Basic Error in Fertiliser Planning" and sent copies of it to ministers, members of Planning Commissions and leading science policy makers, including the Director General of the Indian Council of Agricultural Research requesting comments.

I received a rejoinder forwarded by Dr. M.S. Swaminathan, then Director General of ICAR but written by one Dr. Amiba Singh, then an Assistant Director General of the said Council. The rejoinder started by abusing me and propounded a remarkable thesis, which can be summed up as follows: "In a tropical country, however much you may try, the organic matter status of the soil will not get built up beyond a certain level; and the organic matter status of the soil also cannot go below a certain level: therefore, all that you need to do is to make the soil yield what you want. It has to be fertilised by chemical fertilisers." Now, the first part of the thesis was no doubt correct: the organic matter status of the soil would not build up beyond a certain level, for reasons explained earlier. But from where had the Assistant Director General got the idea that the soil organic matter could not go below a certain level, we are unable to fathom. It is also noteworthy that instead of drawing the conclusion that the tropical soil's tendency towards loss of organic matter needed to be countered by its continuing replenishment, the rejoinder ridiculed the emphasis on organic manuring.

Interestingly, some months later—after OPEC drastically raised the oil price—Dr. Singh sought to withdraw the rejoinder on the plea that the situation had changed. I had to point out that "the issues in the debate were not economic but scientific. If chemical fertiliser was essential for our soil there ought not to be any resiling from it despite the rise in oil price. On the other hand, if it was not suitable for our soil, it should not have been used even if it were available for a song".

There are many social workers who, while preferring organic manure, would still like to use some chemical fertiliser on the grounds that "there is not enough organic manure" and that "there is, therefore, need for adding chemical fertiliser". This reminds me of the question Shri Mohan Dharia had put me many years back when he was Minister of State for Planning in the Government of India: "Is there sufficient organic material to produce the manure?" Shri Dharia had also suggested that there should be some comparative cost studies and cost-benefit analysis. The suggestion was ridiculous. That there could be absolutely no comparison between the cost of producing organic manure from natural material like human excreta, animal dung, plant wastes and that of producing chemical fertiliser through high-temperature, high-pressure operations. The transformation of these wastes into wealth was in any case an imperative because these wastes would otherwise be creating health problems requiring far larger investments in hospitals and in water and air purification. The minister's suggestion was a specimen of vacuous, pedantic phraseologies in high places to scare natural solutions. The answer is an emphatic yes. There is no very great difference, in terms of weight, between our food intake and our waste products. Therefore, if all of our own waste products—i.e. all the stools and urine—are mobilised, these should approximate to the food consumed by us (in terms of weight). If, in addition, the waste products of other animals, the fallen leaves from trees, the plant bodies of legume crops, vegetable refuse, the stubbles from fields, bushes and jungles, tank and canal silt, water hyacinth, husk unusable for fodder, bone meal of dead animals are collected, there would be more than enough organic material to produce the manure. Moreover, there is a limit beyond which even organic manure should not be applied. The application of high doses of organic material may also lead to mineralisation, too much nitrogen being made available that the plant is forced to un-natural growth. About their nutrient content, let there be no doubt. Take the animal wastes first. No biological system can assimilate more than 40 per cent of the nutrients in the food: therefore, a minimum of 60 per cent of the nutrients of the original intake must be present in the excreta. Generally, these contain 60-70 per cent. Then, the other organic material (vegetable refuse, hyacinth, etc.) have rich manurial potential.

The real issue is not whether there is enough organic material to produce the needed quantity or quality of organic manure. The main problem is that we want to avoid the efforts necessary to collect the wastes and prefer the coziness of a push-button system which factory production provides. Moreover, there is a belief that since the 'fertilising' impact of the chemicals is quicker, their addition will lead necessarily to instant incremental production. To those who subscribe to this belief, we would like to put a question: "Are you sure that

this addition of chemical fertilisers will really mean addition of nutrition?" In fact, there is a greater possibility of crop malnutrition.

It is known that nitrogenous fertiliser application usually leads not to better grains but to larger production of stem and leaves. This happens because Nature always seeks to maintain the ratio between total organic carbon and the total combined nitrogen constant in every part of her living empire. An increase in nitrogen, and the consequent lowering of the proportion of carbon sets in motion a process of restoration of the metabolic ratio by inducing more photosynthetic growth i.e. the growth of roots, stem and leaves. In like manner an increase in the proportion of carbon by an abundance of straw and other cellulosic material will also be harmful. It will raise the carbon nitrogen ratio too high. Nature will lock up all the nitrogen in the soil and prevent its availability to the plant. Even if the fertiliser is administered on a genetically dwarf variety and after the tillering stage is over, it will merely increase the number of grains or enlarge the grain size at the cost of bio-synthesis of nutritive elements. This means, its contents of starch, sugars, fats and oils will be more. Grains subjected to this kind of growth are marked by an imbalance in essential amino acids.

A.G. Norman of the University of Michigan had drawn our attention to this aspect in the early sixties. "High yields are not synonymous with a high content of nutrient elements...crops from well-fertilised plots may have a lower content of some essential element (for health) than those from poorly yielding plots; the addition of a fertiliser may cause a reduction in the content of some of the other nutrient elements." Refer to Herbert Lewis in *Our Synthetic Environment,* Publisher: Knopf, New York, 1962.

More recent researches by Dr George Borgstrom, Professor of Food Science and Human Nutrition and Geography of the Michigan State University also support this view. A quarter of a century back, Dr W.A. Albrecht, Chairman of the Department of Soils, University of Missouri (USA) had also warned us against "believing that all the organic or inorganic nitrogen being sold were being converted into proteins".

"Protein production" he said, "is a bio-synthesis—a synthesis by life itself requiring interaction of all the essential elements including trace elements. Even at that time (1958) he had pointed out that for the nutritive value of the crops and the health of the plants, we must first look to the soil—to the geological, the chemical, the biochemical and the biological performances by which the numerous streams of life take off from the soil and continue to flow through the many species of plants and animals." He even pointed to the crucial importance of calcium in growing protein-rich crops. Ironically, the practitioners of "modern" science tend to forget that the application of

power-packed nitrogenous chemical fertiliser on the soil tends to acidify the soil and aggravates its need for liming.

Thus, there is no legitimate basis for welcoming the nutrition-deficient high yielding varieties which merely push up the vegetative bulk and require quick release fertilisers therefore. Nor is there any justification for super charging chemical fertilisers on organic manure.

Quality preparation of organic manure involves blending optimally the carbon, nitrogen, phosphate rich materials, in which the trace elements are present in proportion and the crucial carbon-nitrogen ratio (C/N) is neither too high nor too low. This kind of preparation is within the competence of farmers, given certain guidelines.

There should, therefore, be no question of adding some nitrogenous fertiliser and upsetting the nutrient balance. We refer specially to nitrogenous fertiliser because there is a craze for it on account of its being known as a stimulator of growth and seed production and also because the potential for damage from its unbalanced use is much greater than from others.

In any case, the argument that "chemical fertiliser could be used as a supplement" is misleading. We have yet to see a mass action programme anywhere which, after beginning with "fertiliser as a mere supplement" did not end up as "fertiliser as the main constituent of the nutrient package" in reality.

But we need to delve deeper to know why even some old Gandhian social workers plead for partial use of chemical fertilisers. In my view, this hesitancy to rely wholly on organic processes stems from two sources which are interlinked. One is a lack of awareness of the bounties offered by the nexus of symbiotic interrelationships in Nature. The other is an insufficient awareness of the perils which the efforts of artificial fertilisation invite by way of undermining soil fertility and all other bases of our existence.

Let us first take a look at the bounties in an undisrupted system. Not merely has nature given plant leaves the scope for producing carbohydrates by capturing the carbon dioxide from the atmosphere in the presence of sunlight and with the aid of moisture derived from the soil and for converting these carbohydrates later into sugars, starch, cellulose, lignin etc. She has also made ample provision for the supply of nitrogen through the root system in a variety of ways so that the essential elements of life could be breathed into these sugars, particularly for synthesis of proteins and nucleic acids. Rains wash down the nitrogen generated by thunder. Bacteria in the nodules of leguminous plants capture nitrogen from the atmosphere and fix it into the soil. So do some ferns, some forms of algae and some genera of free living bacteria (azotobacter, clostridium). Various

genera have been endowed with this quality so that this operation could continue under differing conditions.

The benefits of legume crops are often underestimated by our "modern" scientists. It is being suggested that legumes do not leave enough nitrogen in the soil to promote the growth of successor crops. The question is: what is enough? A few days back, in a text book on biology meant for British school students I was reading an estimate that "a good legume crop such as Clover can fix up to 90 kilos of nitrogen gas per acre in one season's growth". I would like to get estimates for our agroclimatic zones. In any case, considering the fact that crop rotations with legumes in between two other crops, sustained India's soil fertility over centuries, despite the decline of the practice of returning wastes to the soil, there is strong basis for the time-tested conclusion that legume's contribution to nitrogen fixation is considerable. Rotational cropping is only next to mixed husbandry in the natural order.

There is yet another very interesting system of nitrogen supply in nature, which is universal in the forests and usual in the orchards and vegetable gardens. When the plant roots, growing in fertile soil, move downwards, active root hairs, abundant fungal threads invade the root cells, only to be absorbed by the latter. These threads may contain as much as 10 per cent organic nitrogen. Besides, their protein quality is well suited to digestion by root cells. This mode of plant nourishment by dense mate of nitrogen-rich fungi is called mycorrhizal association.

Probably the most important source of supply of nitrogen as also of other nutrients is the decomposition of animal and plant wastes. This is done by the decomposer bacteria and fungi.

From these it would be obvious that we can obtain from Nature much more of the beneficially utilisable nitrogen than we are getting now if only we know the pathways of its bounteous flows and cooperate with Nature in her systemic approach.

Nature adopts a somewhat different method in regard to the supply of phosphorous. This is because phosphorous is, unlike nitrogen, chemically highly reactive and it does not at all enter the atmosphere except as dust. Of course, the one method which is basic to all recycling is existent here too: it is the return of the plant and animal wastes to the soil. Animals eliminate excess organic phosphorous by excreting phosphorous salts in urine. There are also the phosphatising bacteria to convert phosphorous into stable forms of phosphate salts which remain bound with the soil. At the beginning of the rains, the mineralisation of organic matter releases phosphates for uptake by the plants. If the phosphate level near the soil surfaces low, but not too low, mycorrhizal roots may form to serve as efficient scavengers of phosphorous. The root-zone micro-organisms, too, may

contain species such as phosphate-bacters which, by secreting phosphate enzymes, liberate phosphates locked up in the soil with compounds of very low solubility. These, too, prove that man has only to be an understanding partner and observe the rules of the game.

For the supply of all other macro- and micro-nutrients as also of vitamins and plant growth promoting substances, there are elaborate arrangements in natural soil systems. The soil abounds in countless forms of micro-organisms—bacteria, fungi, viruses, protozoa yeasts, algae, etc.—to perform different but interrelated functions.

Each produces different kinds of enzymes by which all stand to benefit. This is a highly complex nexus of relationships and a symbiosis of a very high order. High productivity is attainable only if this nexus of relationships is understood and nurtured in creative partnership with nature.

A wonderful fertilising agent of Nature is the earthworm population which, Charles Darwin said, are the "builders of civilisation". Earthworms—which thrive in moist and warm surface soil ingest soil, mix it with secretions from their own guts, and leave a far richer soil cast. These worms concentrate in the cast most of the nitrogen and mineral constituents present in the plant debris, faeces and cuticles of soil anthropods they ingest along with the soil. They are the principal agents for mixing the dead surface-litter more accessible to soil micro-organisms. They are the channelers and burrowers. By loosening the soils, they facilitate air inflow into the soil. By improving the soil structure, they improve the soil's capacity to hold moisture. In their death, too, the earthworms contribute handsomely. Their body tissues may contain up to 70 per cent protein. It is important to remember these facts about earthworms while we discuss organic farming versus chemical farming. Chemical farming tends to kill the earthworms.

An extremely interesting process is observable in nature, which inspires reverence. In the ecosphere, just as there is a building up process working through the leaves (making carbohydrates, proteins and fats and thus building the structure of the plant), there is also a reverse process of breaking down of the soil organic matter into mineral matter. Organic matter is continually reverting to inorganic state to make mineral salts such as compounds of phosphorous, potassium, calcium, magnesium, sodium, iron, manganese, zinc, copper baron so that these could be available for absorption by the plant roots. This breaking down process, apart from feeding the root hairs for the present, provides a reserve of mineral salts for the future. This explains why even in the subsoil regions which underlie the poorest of the poor surface soil, there is always a reserve of mineral chemical constituents, may be in tough combination with others, which can be solubilised by deep-rooting plants.

The mechanism with which Nature endows the plant roots to solubilise these mineral salts of the sub-surface is also interesting. The respiration of the plant roots—which is like mild burning of sugar—releases carbon dioxide from the root hair which dissolves in soil water to form carbonic acid, a mild solvent.

In order to make the essential trace elements available to all, including the shallow-rooting plants in an undisturbed ecosystem, Nature has provided these elements in the upper soil layer itself. These mineral salts, needed in traces, come from the soil humus. They may also come as dissolutions out of, or as dispersions from, the surrounding rocks.

While we sing in praise of Nature's concern for sustenance of life, a question would be uppermost in the minds of the sceptics. Did not the very fact that man had to think of artificially reinforcing fertility show that natural processes had deteriorated or at least failed to deliver the goods? Yes, it is true that the soils have been losing in productivity. But why? It was because we snapped the nexus of relationships. First, the bond between agriculture and its foster mother, the forest, was snapped. The forest is a peculiar foster mother whose sustenance and protective care is needed in space-time continuum. The biotic material from the forest must flow to agricultural fields continuously. The underground water storages, which were many times the volume of lakes, and were the assurance of inexpensive water supply for agriculture could be induced only by the tree roots. And the forests needed to be not only in the hills but also in each village to perform its multiple functions of protection and enrichment. All these avenues we have destroyed in the cause of setting up the trappings for an unsustainable civilisation. Secondly, we avoided the labour of returning wastes to the soil in a form which is beneficial to it. Thirdly, we became partial to certain crops disregarding the benefits of mixed husbandry and rotational cropping and, therefore, became crazy after certain nutrients at the expense of Nature's systemic functioning.

Sceptics might still persist. Once a sceptic had asked me: "If Nature is so beneficent, could it not be a little more generous in supplying nutrients particularly nitrogen, when this element alone constituted 78 per cent of the atmosphere?" The questioner was a technologist and was aware that nitrogen-bearing molecules such as proteins, nucleic acids, enzymes, vitamins, hormones account for much of plant bodies'—and even more of animal bodies—vital functions. That is why, his interest was focussed more on nitrogen. He was also trying to point to the fact that in the gaseous envelope surrounding the earth, nitrogen exists in a form which is not directly usable by the plants. The fact that atmospheric nitrogen is inert and does not enter into chemical reaction with any other element, except under great

pressure appeared to the questioner to be an aspect of unkindness of Nature.

A question like this compels philosophical thinking about Nature's purpose concerning the behaviour of nitrogen, as also of other elements. A little introspection would show that if nitrogen had been easily reactive and if it had been more abundantly capturable, it would have poisoned the environment and dissipated the potential for life's existence. It would have created a profusion of nitrous oxides, the poisonous substance which even pierces the ozone layer. It could have produced many types of proteins that were toxic to living species. It could have also destroyed the very basis of interaction between the living and the non-living matter, i.e. the very condition for perpetuation of life on this planet.

It is to avoid such disasters that Nature had to adopt a double safeguard system. Nitrogen has first to enter this soil, whether by bacterial fixation from the atmosphere or through the decomposition of plant and animal wastes. It is only through the soil that it can enter the plant and animal wastes. It is only through the soil that it can enter the plant and animal bodies. Secondly even the release of nitrogen stored in the soil is not a one shot affair. It has to be in two stages—first, in the form of nitrite and, then as nitrate ions, in which form it is usable by the plants. Plant root hairs can absorb only the minutest of the minute, invisible particle which is electrically charged, that is, charged with the energetics for passage into root cells. If Nature had ordained the release of nitrate in greater doses than were in accord with the proportion of sugars, enzymes etc. being released in the soil sap by other forces, it would not have been useful for plant nutrition. Rather it would have leached to ground water levels and/or drained into surface waters causing nitrate poisoning. It would have also forced the denitrifying bacteria to be more active to release soil nitrogen to the atmosphere. Denitrification i.e. return of nitrogen to the atmosphere is nature's step to maintain the cycle.

It is also significant that "by far the slowest step in this nitrogen cycle is the release of nitrate from the humus". Let us ask ourselves: why did Nature make this the slowest step? Evidently, this was Nature's way to ensure thrifty use of nitrogen so that little nitrate gets released to the water from the soil. As a result, the nitrate content of natural surface water could be low, of an order of one part per million. Those who talk of forced fertilisation, of feeding the plant direct rather than through the soil and of speeding up plant uptake do not care for what happens to the plant cells or to the nitrate or phosphate level of the ground water or surface water. They completely miss the purpose of Nature's slowest step in releasing nitrate from the soil's store of nitrogen.

The solution is not forced feeding of the plants. The solution is to increase the store of natural soil nitrogen and to increase the efficiency of nitrate absorption by the roots. For both, it is the improvement of the humus status which is crucial. Contrarily, chemical fertiliser reduces this very humus. Thereby it perpetuates dependence on more and more chemicals. It is a choice between two roads. Because chemical fertiliser hits at the very core of natural processes, there is no scope of combining the natural and the artificial. It is like opting for smuggling operations. Once you make the choice, the inner logic keeps on working out till the journey's end.

Those who seek to conjugate farming with chemical farming are wasting their efforts in two ways—by engaging in a wholly unnecessary exercise and by trying to unite two entirely incompatible processes, which is impossible.

This is unnecessary because organic manure is not deficient in any nutrient: It is capable of supplying every nutrient to the extent that can be assimilated by the plants healthily. Organic manure, being a complex mixture of hundreds of different organic compounds in various combinations of elements is a storehouse. It releases nutrients gradually so that all nutrients are supplied over a long time in right proportions. Its compounds are subject to minimal loss by leaching. The colloidal product of decomposing organic manure has a high "base exchange" capacity, which means the exchanged ions are not flushed out or wasted. Contact between plant root hairs and the organic manure particles ensures conservation. Thus, there is a built-in economy of supply and demand.

Besides, the organic manure affords a striking advantage. Although all its components start decomposing together, its constituents, on account of their differing hardiness and quanta, require, differing time-scales to decompose, and give rise to variable compositions of micro-organismic populations in succession. All the products of decomposition are available till the end and there is no shortage of any nutrient at any time. Thus, there is a sequence and yet a continuity in this harmonic process of organic manure decomposition. And there can be no question of imparting greater sufficiency than the fullness that a well-prepared organic manure gives.

The attempt to bring under a common harness the organic manure and the chemical fertiliser is like employing some disruptive elements along with a cooperatively functioning team, in wishful disregard of their antagonistic relations, with the result that the cooperative elements are prevented from doing their jobs. Here, too, Gresham's Law operates. Just as the bad coin drives out the good coin and the rogues in a team drive out the good people, the chemical elements force the naturally forming element to recede more and more into nothingness. We shall see a little later how the pro-

cess works. It is not possible to integrate a disruptive approach and a building-up approach in one programme.

For a proper understanding of exactly how the beneficial effects of organiç fertilisers get reduced by the mixed application of organic manures and chemicals, it is necessary to know the interacting relations between the myriad forces involved—the behaviour of soil particles with their constituent elements, soil micro-flora and fauna, soil solution, etc.—and the rhythm, sequence, symphony of natural systems. Instead of burdening the present article with these intricacies, let us briefly state here that the addition of chemical fertiliser detracts from the beneficial effects of organic manure, and causes harm, in the following ways:

a) Application of chemical fertiliser over and above organic manure is likely to produce an excess of nitrogen and even of phosphate. An excess of any element causes damage. In the case of nitrogen, we have earlier stated that its excess leads to dilation of cells, diminution of flowering, and weakened resistance against diseases. Excess of phosphate, beside polluting water, does other kinds of damages. Thus, the addition of chemical fertiliser is both a waste of resource and an invitation to injury. The injury is reflected in (i) lesser yield in the total food package from the overall husbanding of the given land; and, (ii) loss in nutritive quality.

b) Whereas organic manure consists of 30-40 elements of very minute strength, the chemical fertiliser contains only five or six selected elements in high concentrations, in the form of compounds. This results in an increase in the density of salt in the soil solutions, which means difficulty in water absorption by plants. This becomes more evident in rabi (winter) crops. In kharif (i.e. rainy season) crops, the problem gets largely resolved by washout of salts. So, there has to be either washout i.e. wastage, or the plants have difficulty in water absorption.

But there is an even more serious problem. Non-tailored plants are not able to withstand frequent shocks through osmotic pressure variations resulting from repeated fluctuations in salt density in the solution; only the weeds are. Hence any use of chemical fertiliser prepares the ground for take over by weeds. Of course, tailored plants like the "high yielding varieties" are designed to take these shocks. But there, too, Nature takes revenge by making these varieties pest-prone and obsolete every three to five years.

c) It disturbs the entire micro-flora and micro-fauna of the soil.

It de-activates and even kills the nitrogen fixing bacteria and decimates all those bacteria which fix sulphur, iron, carbon, hydrogen, etc., in their own bodies initially and contribute these elements to the soil organic matter while dying. When these bacteria

are thrown into disarray, the disease producing bacteria thrive on account of the disproportion of salts.

d) The use of chemical fertilisers, even in the presence of organic manure, upsets the sequence of decompositions, and hence both the successional order and the balance of micro-organismic populations. Different types of organisms are endowed with different functions and follow a line of succession relevant to the changing character of the substrata. In a natural system, there are many species of micro-organisms at any time. They assimilate carbon gradually. In their death they contribute to the organic matter to nourish the succeeding generations. But when the concentration of certain elements is selectively and artificially increased, it encourages excessive multiplication and overactivity of certain types of bacteria which are relevant to these salts. At the same time, it de-activates and kills the more useful types of bacteria.

Thus, two distinct developments take place. The latter (i.e. the more useful) types of bacteria die without doing their job and without getting a chance to multiply. The former types decompose and deplete the organic matter too fast, preventing its long term function.

e) The use of chemical fertiliser, even with organic manure, affects both the physical and chemical structure of the soil. Apart from causing a loss of natural nutrients, it results in a loss of filth and water holding capacity, which opens up a vast panorama of serious consequences. All the benefits of aeration and moisture retention and hence all the biological processes which are based on soil water and air, tend to get reduced and ultimately evaporate.

Along with these, the plants' strength to draw the nutrients diminishes. By shutting out the natural nitrogen, these processes keep on raising the need for chemicals and at the same time keep on decreasing the soil's capacity for their absorption. It is important to remember that organic manure can at best moderate the evil consequences for some time. It can neither prevent the consequences nor restrain these for long, just as good men forced into a company of evil and aggressive persons cannot act together for long.

f) The higher-than-normal concentration in the soil of the selected salts affects the balance in micro-elements which is extremely important for plant health. These compounds set off a chain of recombinations with other forms of salts. As a result, certain ions get themselves attached to soil particles by knocking off certain others. The knocked-off elements get leached out of the soil. This may mean toxicity caused by the excess of certain elements and shortages of certain other elements. Also, as a result of new combinations, certain elements become insoluble and unavailable to plants.

g) Whereas an organic mass generally maintains balance of trace

elements, the addition of chemicals affects this balance. This is because many of these micro elements are sensitive to large changes in the concentration of cations. For example, when ammonium ions are too high in relation to potassium, the plant tissues are likely to get killed. Excess of phosphate on calcareous soils may lead to zinc deficiency. Ammonium sulphate may leach out calcium. When calcium gets depleted, the species of legumes which are calcium-demanding will not grow. Use of ammonium sulphate increases magnesium availability and hence the possibility of magnesium toxicity on acidic soil. High sulphate availability may cause copper deficiency. Calcium can pick up phosphate from sodium and potassium and immobilise it. If potassium sulphate and calcium nitrate happen to be added at about the same time, this will create calcium sulphate which is insoluble. Chemical compounds generally tend to make iron, manganese, boron insoluble.

h) There is the phenomenon of antagonism between salts. If we put phosphate and also iron or calcium, it will antagonise the absorption of phosphate with calcium/iron. The phenomenon of ionic competition for diffusion into the plant body further complicates the situation. If sodium and calcium happen to be equivalent to potassium in concentration, the sodium/calcium will prevent the entry of potassium into the plant body.

The importance of balance in trace elements is often overlooked though homage is paid to it in theory. These are "life chemicals" needed in small quantities. They are present in the soil in such small quantities that these are mentioned as parts per million and in some cases, even per billion. Yet, the deficiency or excess of any of these elements affects the growth and certainly the vitality of the plant. Discoloration and death of the growing plants are among the manifestations of micro-element deficiency. When there is a deficiency of several elements, even the quantity of yield may turn out to be quite low. This happens under a law of Nature which is called the Law of the Limiting Factor. Even though the original formulator of this law, Liebig, had adumbrated it with reference to only the macro-elements and this had led to an overemphasis on the importance of nitrogen, phosphate and potassium (NPK), the law is valid with reference to micro-elements, too. According to this law, it is the nutrient which is most deficient that decides the level of nutrition. This phenomenon in farming can be explained by an analogy from transportation. The odd vehicle which adopts three tyres from a Rolls Royce and one tyre from a Fiat is limited in its speed by the capacity of the Fiat tyre.

A peculiarity of the trace elements is that these are normally all very poisonous, if present in the soil in more than very minute quantities and in a form readily available to plants. Hence it is

dangerous to administer these minerals/elements artificially. To the contrary, the organic manure, being a bulk of organic substances, nearly always maintains a balance of these elements. It is well nigh impossible to maintain a balance of micro-elements if chemical fertilisers are used.

In Nagarjun Sagar area in Andhra Pradesh, an excess of molybdenum was reported to be poisoning the plants. Wide spread zinc deficiency is reported from Punjab and Haryana. The farmers in the latter states are now applying zinc in small dressings. But what will happen when several more elements will start showing pronounced imbalance? Can this matter be left to the guessing game of humans?

There is a kind of harmonious relationship between the soil, plant and the microbial population. Application of chemical fertiliser, even with organic manuring, means disturbance to the harmony. It is analogous to an effort at orchestration with provision for some overactive drums and some superfast tablas.

The effect of applying chemical fertiliser, even with organic manure, can be gauged by linking up two palpable facts. Nowhere in the world does a farmer like to expose his field to chemical fertiliser alone. He uses some organic manure. This has not prevented the ill effects. Between 1882 and 1952, the area of world desert rose from 1100 million hectares to 2600 million hectares. This expansion of desert was indeed attributable to deforestation and the pulverisation of soil arising from the use of chemical fertilisers

Findhorn and the Garden of Eden

By Peter Tompkins and Christopher Bird

The most advanced experiment involving human communication with plants has developed in a remote corner of northern Scotland. On a barren, wind-blown patch of gorse and sand overlooking the Firth of Moray, near the heath where the three prophetic witches met Macbeth, an ex-R.A.F. Squadron Leader turned hotel-keeper decided to settle with his wife and three young sons in the derelict corner of a caravan park on Findhorn Bay—a rubbish heap of old tin cans, broken bottles, brambles and gorse bushes. He was tall and ruddy and his name was Peter Caddy. Once he had walked two thousand miles in the Himalayas, crossing Kashmir deep into Tibet, and since young manhood he had been a follower of a school of adepts whose object was to bring back beauty and wonder to this planet. With his

wife, Eileen, and with Dorothy MacLean, both of whom he considered "sensitives" Caddy pulled up his roots and moved to Findhorn one snowy November day in 1962.

For some time the Caddys had been intent upon radically changing their lives by turning away from materialist pursuits in order to enter upon what Caddy calls a long period of training and preparation during which they would surrender everything, including all personal volition to what they term "limitless love and truth". To be fair, the one place the Caddys least expected to settle was the unsightly, overcrowded encampment of mobile houses known as Findhorn Caravan Park. For years they had scornfully hurried past it on their way to and from Forres. Now some mysterious force was overriding their aversion and guiding them to their new home, less than half an acre in a hollow not far from the main cluster of caravans. It was a patch of land composed mainly of sand and gravel, constantly swept by gale-force winds, only partially protected by a belt of spiny fir trees and tufts of broom and marram grass which kept the soil from blowing away. With winter coming it was a dismal prospect. Following the concept of the monks who used to build their monasteries by hand, putting love and light into the fabric of the building with every stone they laid, the Caddys cleaned and painted their caravan from top to bottom and polished all the furniture. Devotedly cleansing and hand-painting the caravan was a first step towards the creation of their own centre of light. Partly to increase this protective shield of light around them and partly as a source of healthy nourishment, they dreamt of establishing a garden once the dark Scottish winter was over.

During the short days and long nights Caddy pored over gardening books which he found contradictory in their recommendations. Written for horticultural enthusiasts living mostly on the mild south English coast, they were irritatingly irrelevant. He had never sown a vegetable seed in his life and felt like Noah when guided to build an ark where there was no water; but he dutifully forged ahead. Guidance was to be followed to the letter, or they might as well return to the world of business. His Rosicrucian master had taught him one prime rule of life: "To love where I was, love whom I was with, and love what I was doing."

To receive the arcane guidance on which the infant community planned its every move, Eileen would rise regularly at midnight and meditate for several hours, bundling herself in an overcoat against the chill of the Scottish nights. She had read in a book that everyone receives his spiritual name at some point in life and that only then can he begin his spiritual work. In 1953 she had felt the word Elixir branded on her forehead; so she adopted the name, and from then on her guidance was constant.

In her inner vision Elixir now saw seven cedarwood bungalows clustered together, in the midst of a splendid garden, all trim and neat. How this vision was to materialize in the constricted squalor of the caravan site remained a mystery. Yet all were prepared to put their faith in her vision.

The prospect of creating a garden seemed a superhuman task. The ground was made of fine dusty sand and gravel in which nothing grew but tough pointed grass. But Caddy cheerfully began to dig a strip of quitch turf three feet wide by nine feet long and laid it to one side. He then dug down eighteen inches, accumulating a pile of sand and gravel. In the clean trench he placed the strip of quitch turf upside down and broke it up with his spade. This was to ensure that the turf would not sprout its way back up to the surface, but provide nourishment as it disintegrated. After many hours of patient digging, raking out of stones and finally spraying with water, the plot was ready for seeding.

According to the local agricultural experts, and the available textbooks on gardening, nothing could be grown in the Findhorn soil except perhaps a few lettuces and radishes. Scanty fare for a family which had become accustomed at their hotel to daily steak or duck washed down with good red wine. Nevertheless, Caddy conscientiously sowed his lettuce seeds. To fend off the ever-present winds blowing across the Moray Firth, the Findhorners needed a slatted fence. Almost miraculously, the necessary wood was forthcoming from a man who was dismantling his garage. As soon as the fence was up a neighbour ran over to say that some barely damaged bags of cement had fallen from a truck across the road. In a short while they had a fenced concrete patio from which to admire not thriving young lettuce, but stunted apparitions, attacked by wire-worms. Then, a neighbour chanced to pass and informed Caddy of a pile of seasoned soot just outside the entrance to the caravan park, an admirable antidote to wire-worms.

By the end of May they were eating luscious lettuces and radishes. A compost heap was essential if they were to grow a greater variety of vegetables, without the use of chemical fertilizers. Once again, a neighbour gave them a pile of rotting grass and a nearby farmer, grateful for a rescued sheep, gave Caddy a large load of cow manure. A friend who owned a riding stable allowed them to follow his horses with a bucket and a shovel. A nearby distillery supplied them with free peat dross and cummings, a potent barley germ fertilizer. They gathered seaweed from the beach. A bale of hay dropped from a passing truck almost at the gate of the park served to cover the compost heaps. Relying on such "supermundane assistance" the Findhorners acted as if they were endowed. As one of them wrote: "We could have been negative and said the soil was

useless—as it was. Instead we put hard work and positive thought into everything we did."

Caddy worked from morning till night, putting sweat and radiations into the soil, his object being to grow enough vegetables to provide a large part of their diet in the months to come. The pure air, sunlight, sea bathing and plenty of cold, pure water, would, they hoped, purify their bodies and endow them with energy.

The theory was that the more refined their bodies became the more they would be able to absorb cosmic energies and the less solid food they would need. They planted watercress, tomatoes, cucumbers, spinach, parsley, marrow and asparagus. They planted hedges of blackberries and raspberries round their garden which was now spreading beyond the caravan till it covered two acres of ground, every bit of soil of which had to be manufactured from old turfs and new compost, every square inch manhandled several times in the process.

The neighbours were incredulous, especially when only the Caddys' cabbages and sprouts survived a plague of cabbage root grubs, and only their black currants grew healthily when the crop had largely failed in the rest of the county.

Findhorn lunches consisted of salads with over twenty ingredients; surplus quantities of lettuce, radishes, spinach and parsley were disposed of round the neighbourhood which was suffering a shortage. Their evening meals included two or three vegetables from the garden, freshly picked and freshly cooked. Stews from garden vegetables consisted of onions, leeks, garlic, carrots, parsnips, swedes, turnips, artichokes, kohlrabi, celery, marrow, potatoes, flavoured with all kinds of herbs.

Elixir was told to let her mind dwell on each ingredient as she cooked, and that her thoughts and feelings were important in the continuing cycle of life. She was to appreciate whatever she was doing, whether peeling a carrot or podding a pea, and to consider each vegetable as a living thing in her hands. Of the peelings and garbage nothing was to be wasted. All was to go back into the compost and the soil, constantly increasing the live vibrations.

When autumn came they were ready to preserve quantities of raspberries, blackberries and strawberries, putting up altogether a hundred pounds of jam. They pickled fifteen pounds of red cabbage, and large quantities of cucumbers. In a newly built garage they stored potatoes, carrots, beetroot, and the shelves were laden with shallots, garlic and onions. During the winter they prepared the earth for the following season and planted more fruit trees and bushes, including apples, pears, plums, greengages, cherries, apricots, loganberries and boysenberries. By May 1964 the fruit trees and

bushes were bursting into bud. When the red cabbages matured one weighed a massive thirty-eight pounds and another forty-two. A sprouting broccoli mistakenly planted as a cauliflower grew to such enormous proportions that it provided food for weeks; and was almost too heavy to be lifted from the ground. By this time they were growing sixty-five different kinds of vegetables, twenty-one types of fruit and forty varieties of herbs.

In June 1964 when the County Horticultural Adviser came to take a sample of the soil for analysis, his first comment was that the soil would require a dressing of at least two ounces of sulphate of potash per square yard. Caddy replied that he did not believe in artificial fertilizers, that he was happy using compost and wood ash. The adviser said that would be totally inadequate.

Six weeks later when the results of the analysis arrived he was forced to acknowledge that there were no deficiencies in the soil sample. All necessary elements, including rare trace elements, were present. He was so astonished by the results that he asked Caddy to take part in a broadcast about the garden in which he, the adviser, would take the chair and an experienced gardener using conventional methods with chemical fertilizers would debate with Caddy. This Caddy did, attributing his success to organic manure and compost. He did not feel that the time was appropriate to expound on the spiritual side of their endeavour. By this time Caddy was convinced that there must be some greater underlying purpose in their pioneering venture at Findhorn. Perhaps it was the nucleus of some larger experiment in group living, a sort of training course in the realization that Life is a whole. For some time Dorothy McLean, who had been receiving spiritual guidance of her own, and had adopted the spiritual name of Divina, had been studying the aromatic plants in the garden and found that their unique wavelengths could affect different parts of the human anatomy as well as the human psyche, some plants being good for wounds, others for eyesight, others for human emotions. She realized that by raising the quality of her own vibrations she might eventually open the doors to a whole new spiritual realm of plant life. It became clear to her that plants are most susceptible to human thoughts and emotions, and that their energy can be affected. Poisonous and bad-tempered moods have as depressing an effect on plants as happy uplifting frequencies have a beneficial effect. Not only that, but the bad effects could come back to humans as they ate the produce they had infected with bad vibrations. Thus the cycle could become either viciously descending, leading to more and more misery, pain and disease, or hopefully ascending, leading to greater joy and greater light. Thus the most important contribution that man can make to his garden—even more important than water or compost—is the radiation in the form of strength, love

and happiness which he puts into the soil while cultivating it. But there are other radiations besides the human ones that affect the soil and plants; those from the earth itself and from the cosmos, each of which contribute to fertility, and without which they would be sterile.

In the spring of 1967 Elixir received guidance that the garden was to be extended even further and made into a place of beauty. The centre was to be expanded and new bungalows built. The vision she had first received on arriving at Findhorn was now beginning to materialize. Money for neat cedarstrip bungalows turned up as if by miracle, and the bungalows were soon surrounded by impeccable flower gardens.

In 1968 Findhorn was visited by a number of accomplished gardeners and agricultural experts who were amazed at its remarkable success despite the poverty of the soil and the rigorous northern climate. When Sir George Trevelyan, a leading member of the Soil Association, came at Easter the daffodils and narcissi were the largest and most brilliantly coloured that he had seen. The root vegetables were the best he had ever tasted. Many fruit trees were in blossom and a vigorous young chestnut stood eight feet high among broadleaved trees and shrubs thriving on the landward slope of windswept dunes. Sir George said he had seen enough to know that compost and straw mulch alone, mixed with poor and sandy soil, was not enough to account for such a garden. He therefore wrote to Lady Eve Balfour, the Hon. Secretary of the Soil Association, that there must be some Factor X to be taken into consideration, adding that if so much could be accomplished at Findhorn in such a short time, the Sahara could be made to blossom.

Other visitors to Findhorn were equally impressed by the superb produce and felt that such results could not have been achieved on such barren soil by means of compost and good husbandry alone. There must be some other factor to account for it.

Lady Mary Balfour, sister of Lady Eve, who describes herself as an "ordinary gardener of the organic school" spent twenty-four hours at Findhorn in September of 1968 and wrote:

"The weather throughout was grey and at times wet. Yet in retrospect I can see that garden in brilliant sunshine without a cloud in the sky, which must be due to the extraordinary brilliance of the blooming flowers I saw there. The flower beds were all a compact mass of colour."

Professor R. Lindsay Robb, a United Nations agricultural expert and professor of agriculture at various universities, visiting Findhorn just before Christmas one year, went on record to say that:

"The vigour, health and bloom of the plants in the garden at mid winter on land which is almost a barren powdery sand cannot be

explained by the moderate dressings of compost, nor indeed by the application of any known cultural methods of organic husbandry. There are other factors and they are vital ones."

Eventually Peter Caddy confided to Sir George Trevelyan the secret of their success at Findhorn. Dorothy McLean had apparently managed to get into direct contact with the Devas or angelic creatures who control the nature spirits that are said by clairvoyants to be everywhere at work nurturing plant life. Sir George, an advanced student of the arcane, and of the hermetic sciences, admitted that he was aware that a number of sensitives claimed to be in touch with the devic world and to be working with it, and that Rudolf Steiner had founded his biodynamic methods on such knowledge. Far from scoffing at Caddy's explanation he was prepared to give it credence and to validate it by suggesting that conscious investigation of such worlds is of the utmost importance to our understanding of life, and especially our understanding of the life of plants.

After this Peter Caddy published a series of pamphlets describing the true nature of the experiments at Findhorn. Divina contributed with detailed descriptions of the messages she said she received directly from the Devas of which she described whole hierarchies responsible for every fruit and vegetable, for every flower and weed. Here was a Pandora's box more phenomenal than the one opened in New York by Backster.

Findhorn quickly developed into a community of over a hundred members. Young spiritual leaders turned up to preach the gospel of a New Age, and a college was founded to teach its tenets. What had started as a miraculous little garden appeared to be turning into a true centre of light for the Aquarian Age, visited annually from every continent of the globe.

Parting the veil into other worlds and other vibrations beyond the limits of the electromagnetic spectrum may well go a long way to explain the mysteries which are incomprehensible to physicists who limit their outlook to what they can see with their physical eyes and their instruments. In the world of the clairvoyant, who claims to have mastered the art of etheric and astral vision, a whole new series of vistas opens up around plants and their relation to man, to the earth and to the cosmos. The growth of seeds and plants, as Paracelsus intimated, may indeed be affected very strongly by the position of the moon, the position of the planets, their relation to the sun and to the other stars of the firmament.

Fechner's animistic vision of plants being ensouled becomes less of a wild conceit, as does Goethe's concept of a prototype plant. Burbank's knowledge that whatever man wishes he can produce with the aid of nature or Carver's insistence that nature spirits abound in

the woods and take part in the growth of plants may have to be reviewed in the light of the discoveries of the Theosophists and especially of such extraordinary seers of nature spirits as Geoffrey Hodson. The ancient wisdom, as detailed by seers like Mesdames Helena P. Blavatsky and Alice A. Bailey, throws quite another light on the energy of bodies, both of humans and of plants, as well as the relation of individual cells to the entire cosmos.

The secret behind Pfeiffer's biodynamic compost, which has been proved so highly effective scientifically, turns out to be a homeopathic wonder based on a fairyland creation of Rudolf Steiner's organic brews made by burying cow horns filled with cow dung and deer bladders filled with nettles and camomile leaves. Steiner's anthroposophy, or Spiritual Science, throws such a light on plant life and agriculture as to make scientists root in their tracks.

Aesthetically, the world of the devas and the nature spirits turns out to be even more full of colour and sound and perfume than the creations of Scriabin and Wagner, their gnomes, nymphs, and undines, their fire, water, earth, and air spirits closer to reality than the Holy Grail and the eternal quest it engendered. As Dr Aubrey Westlake, author of *Pattern of Health*, describes our imprisoned state, we are locked in a valley of materialistic concepts, refusing to believe there is anything other than the physical-material world of our five senses. For we, like the inhabitants of the country of the blind, reject those who claim to have "seen" with their spiritual vision the greater supersensible world in which we are immersed, dismissing such claims as "idle fancies" and advancing far "saner" scientific explanations.

The attraction of the seer's supersensible world, or worlds within worlds, is too great to forgo, and the stakes too high, for they may include survival for the planet. Where the modern scientist is baffled by the secrets of the life of plants, the seer offers solutions which, however incredible, make more sense than the dusty mouthings of academicians; what is more, they give philosophic meaning to the totality of life. This sensible world of plants and man only touched on in this volume, will be explored in another, *The Cosmic Life of Plants*. (Taken from *The Secret Life of Plants*. 1973. pp 310-319)

Permaculture

By Bill Mollison

Permaculture (permanent agriculture) is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their food, energy, shelter, and other material and non-material needs in a sustainable way. Without permanent agriculture there is no possibility of a stable social order.

Permaculture design is a system of assembling conceptual, material, and strategic components in a pattern which functions to benefit life in all its forms.

The philosophy behind permaculture is one of working with, rather than against, nature; of protracted and thoughtful observation rather than protracted and thoughtless action; of looking at systems in all their functions, rather than asking only one yield of them; and of allowing systems to demonstrate their own evolutions. (Taken from *Permaculture*. 1990. pp ix-x)

I believe that unless we adopt sophisticated aboriginal belief systems and learn respect for all life, then we lose our own, not only as lifetime but also as any future opportunity to evolve our potential. Whether we continue, without an ethic or a philosophy, like abandoned and orphaned children, or whether we create opportunities to achieve maturity, balance, and harmony is the only real question that faces the present generation. (p.2)

We can imitate the structure of natural systems. If we have palms, vines, large evergreen trees, an edge of herbaceous perennials, a ground cover of bulbs or tubers, and a rich bird fauna in the natural system of the region, then we can reconstruct or imitate such a system structure on our site, using some native species for pioneers, bird forage, or vine supports. We can add to this the palms, vines, trees, tubers, and poultry that are of great use to our settlement (over that broad range of uses that covers food, crafts, medicines, and fuels).

After studying the natural placement of woody legumes or windbreak in natural systems, we can imitate these in designed systems. We can improve on local species by finding out-of-region or exotic species even better suited to those roles than those of an impoverished or degraded native flora and fauna. Certainly, we can carefully select species of a wider range of use to settlements than the natural assembly. (p.45)

Let us now be clear about how trees affect total precipitation. The case taken is where winds blow inland from an ocean or large lake:

1. The water in the air is that evaporated from the surface of the sea or lake. It contains a few salt particles but is clean. A small proportion may fall as rain (15-20%), but most of this water is condensed out of clear night air or fogs by the cool surfaces of leaves (80-85%). Of this condensate, 15% evaporates by day and 50% is transpired. The rest enters the groundwater. Thus, trees are responsible for more water in streams than the rainfall alone provides.

2. Of the rain that falls, 25% again re-evaporates from crown leaves, and 50% is transpired. This moisture is added to clouds, which are now at least 50% tree water. These clouds travel on inland to rain again. Thus trees may double or multiply rainfall itself by this process, which can be repeated many times over extensive forested plains or foothills.

3. As the air rises inland, the precipitation and condensation increases, and moss forests plus standing clouds may form in mountains, adding considerably to total precipitation and infiltration to the lower slopes and streams.

4. Whenever winds pass over tree lines or forest edges of 12 m (40 feet) or more in height, Ekman spirals develop, adding 40% or so to rainfall in bands which roughly parallel the tree lines.

5. Within the forest, 40% of the incident air mass may enter and either lose water or be rehumidified.

6. And, in every case, rain is more likely to fall as a result of organic particles forming nuclei for condensation, whereas industrial aerosols are too small to cause rain and instead produce dry, cloudy conditions.

Thus, if we clear the forest, what is left but dust? (Taken from *Permaculture*, p.150)

Permaculture or Permacult?

By Winin Pereira

In the last few years there has been an increase in interest in Permaculture, with many seminars and much promotion of the system. I have been getting some unsettling feedback on this, so I feel that a thorough debate on it is necessary. I have put down a few points here for discussion and I hope that, because of your interest in sustainable and safe farming, you will respond to them.

After hearing from some who had attended seminars, I borrowed a book on Permaculture. (Bill Mollison, *Permaculture, a Designers' Manual*, 1988). This is a huge volume with 580 large pages of dense print. A close reading of just a few pages has led to the conclusion that Permaculture should not be recommended and should be used with the utmost caution here.

The very basic principles of Mollison's philosophy are sound: "Working with, rather than against nature; of protracted and thoughtful observation; rather than protracted and thoughtless action, of looking at systems in all their functions, rather than asking only one yield of them; and of allowing systems to demonstrate their own evolutions." (ibid, p.ix) But they are not Mollison's principles: these are what our ancient Indian sages—and most indigenous cultures worldwide—have recommended centuries ago, and what those who are uncontaminated by western culture still practice today.

Mollison mentions many good points, like food storage in tubers, obtaining a variety of foods throughout the year, fail-safe crops mixes, etc. These have also been used here for ages. Unfortunately, we have a tendency to reject our traditional knowledge and practices, while we uncritically accept what foreigners say, even when they are giving us our own knowledge in a grossly distorted and expensive form.

But worse, Mollison does not follow these principles himself. If he had contented himself with describing the complexity of natural interactions in particular environmental niches—which he does well for mainly Australian conditions—and with giving descriptions of natural phenomena which are correct and informative, his book would be valuable. But to extrapolate from such principles to recommending specific configurations of trees and crops is absurd. The very idea of "conscious design and maintenance" contradicts the principle of working harmoniously with nature.

Designing implies that he—the expert—is aware of all interactions in particular ecological niches. This can never be, particularly so in a country with which he is not familiar. Design, therefore, can only be done by making numerous simplifying assumptions, which al-

most surely will result in harm if put into practice. Such advice is definitely not scientific. Nature is simply too complicated to be planned and managed. It is precisely this over-simplification which is the root cause of the failure of the western synthetic agricultural system. Perhaps, Mollison's emphasis on design is a subconscious attempt to dominate nature, a desire which impermeates most of western culture.

In a recent Permaculture seminar (for which the charges were Rs 2,200 per head), detailed designs for windbreaks were provided. Here the advocates of Permaculture attempt to change the natural micro-climate to suit the crop that they want to cultivate. The "natural" thing to do is to select a crop to suit the climate. It is very noticeable that the plants Mollison writes about are mainly non-Australian ones which have been introduced into Australia and are not suitable for the Australian environment. Hence his need to modify the climate there. But, if he believes in his principles, then he should seek out Australian plants that suit the micro-climate of the region in which he is working. Europeans have played havoc with Australia's natural flora and fauna by bringing in exotic plants and animals. Bringing in more exotics does not correspond with working with nature. Perhaps he has a need to recommend exotics because he is himself an exotic, transplanted to an alien country.

His advice naturally degenerates still further when he makes recommendations for non-Australian countries. He gives numerous suggestions for the use of specific plants all over the humid tropics, for instance, when soil and climatic conditions change even over a few metres.

I have it purely on hearsay that, at a seminar in Mumbai, Mollison recommended that paddy cultivation be replaced by other crops which could be more productive. If this is correct, then it is evident that Mollison hasn't the faintest idea of Indian environmental conditions. Because paddy fields are bunded, they store an enormous quantity of water and without them there would be disastrous floods after every heavy shower of rain. Further, without the bunds there would be so much erosion that all top soil from paddy-growing regions would be lost in a few years. The flooded fields also provide an environment where nitrogen-fixing blue-green algae and azolla thrive, and where frogs and fish catch pests and provide food. Only a few other food plants can thrive in such an environment.

In one Permaculture "design" for an Indian farm, trees are to be planted in precise semi-circles for windbreaks. Only two—foreign—species were recommended even though there are dozens of local species which would be more suitable. To reduce noise, the trees are to be planted in triangles. Here it is thoughtless action rather than thoughtful observation that is in operation.

The whole design is pseudo-scientific—which unfortunately seems to impress many people, particularly when they have to pay heavily for it.

The trees recommended for windbreaks were casuarina and silver oak. Both are Australian species, neither has medicinal or food or other use besides wood. While casuarina is a nitrogen-fixing tree, it cannot fix nitrogen unless uncommon Frankia species of microorganisms are available in the soil, which is unlikely in most areas here. Casuarina is allelopathic—it prevents other plants from growing near it. Further, casuarina and silver oak do not coppice well, and they do not support birds and probably other wildlife, too. They do provide pollen for bees but Casuarina pollen is well known for causing allergic reactions; newly introduced species are reported to cause more severe allergies than those to which people are accustomed. In the last drought, a large number of casuarina and other exotic trees died, while local species did not. In the storm last year around Mumbai, many of them just broke off while indigenous species withstood the high winds.

Silver oak performed poorly in plantations in Australia itself and it is no longer of commercial importance in its native land. It has been found to be a contributing factor to outbreaks of a harmful fungus, Armillaria mellea, in coffee and tea plantations in Africa, and had to be completely destroyed. Silver oak does not fix nitrogen and its leaves have poor palatability as fodder. Its sap and sawdust causes skin irritation in some people. It cannot stand seasonal drought and it loses much of its leaf cover in the drier winter months in its natural habitat.

Other examples of exotics recommended are Tipuana tipu which is not abundant even in its native lands of Bolivia and Argentina. Also recommended is the herb comfrey, Symphytum officinale, which has toxic pyrrolizidine alkaloids and is known to produce liver and bladder tumours in rats. It is wrong to promote such plants without also giving warnings about their use.

When exotics are introduced into a stable ecosystem, there are possibilities of large imbalances being produced, since their symbiotic microorganisms, insects, animals and even plants are never brought in with them. This is not to say that exotic plants can never be useful—many of them have proved beneficial all over the world. But new ones should not be introduced when much better local ones are available.

Mollison states: "The real difference between a cultivated (designed) ecosystem, and a natural system is that the great majority of species (and biomass) in the cultivated ecology is intended for the use of humans and their livestock." [ibid, p.7] He is evidently unaware that in India—and in most of the Two-Thirds World, nearly all

plants, wild as well as cultivated, have multiple uses. But, more important, all trees and creatures have an intrinsic value, which is what those who respect nature understand.

"Make the least change for the greatest possible effect. For example, when choosing a dam site, select the area where you get the most water for the least movement of earth moved." [ibid, p.15] This is very simplistic. He does not consider submergence of land and trees, displacement of people, loss of species, and so on.

"Where we MAINTAIN such diversity, as in our gardens, then this may guarantee yield, but if we leave our gardens, they will simplify or simply be obliterated by non-maintained or hardy species adapted to that site." (emphasis his) [ibid, p.32] Here in India—even in a city like Mumbai—if we leave gardens alone, they become more complex, with a large number of species of herbs, shrubs and trees growing naturally. Leaving nature to work its own way is the method of harmonising with nature, and this will tend to maximise biomass and biodiversity and give a wide variety of useful products. Mollison's problem arises because he is trying to grow exotic plants in Australia and it is probably indigenous "hardy" species that try to reclaim their heritage. But he does not seem to have studied local plants and he is totally unaware of the multiple uses of "weeds".

His basic false assumption is that we can learn more than what nature knows, that we can improve on nature and "design" it. He states correct principles but squeezes out DESIGNABLE interventions from them. He seems to unnecessarily make things complicated—the characteristic of an "expert"?

Mollison's idea of self-reliance is limited to food and energy. But even this is contradicted since he recommends many outside inputs which all involve energy use. For instance, he recommends terrace gardens in cities to grow food, but much outside energy is required to pump water from distant sources, and this makes such a system unsustainable. Further, he freely recommends the use of mechanical transport, greenhouses, bulldozers and concrete, and other products of "high" technology. All these products, which depend on non-renewable energy for their manufacture and use, and which are made of non-renewable raw materials in large quantities, promote unsustainability. The setting up of an $8-million-project, in a place called Crystal Waters, to build the "community for the future", make claims for self-reliance and sustainability extremely doubtful.

The extent to which Permaculture affects Indian culture is exemplified by a statement made by one of its protagonists in a local Permaculture newsletter. "Humankind has built several kinds of systems over the last couple of centuries. All of them have proved unsustainable resulting in the erosion of all life forms."

The first sentence is brazenly racist, since it is true only if "humankind" is identified solely with "whites". All peoples had sustainable systems thousands of years ago but it was mainly the Europeans who first destroyed theirs and then set about destroying those of other indigenous peoples elsewhere. Many of the latter still have them now. [see *Asking the Earth*, Winin Pereira and Jeremy, 2nd impression, 1996] Mollison's followers are so conditioned that they ignore the fact that such sustainable systems existed in their own country or they deliberately spurn them so that they can promote Mollison's system.

Only a few illustrative points have been mentioned here since an analysis of the whole book will require another book, and producing such books is not conducive to sustainability even if 50 c of the price of each book is supposedly used for tree planting. Contradictions abound in his book, because designing nature is itself a contradiction. Further, the style of writing is so repetitive and obtuse that unearthing all the errors and inconsistencies is laborious. His stuff may be new to the west, but it should not be brought in here as something novel. No doubt it is an improvement over western agriculture, but it has a long way to go before being better than our own traditional systems. And to blindly recommend his practices can lead to much wasted effort and energy and cause great environmental damage.

There is no way in which the majority of farmers can follow Mollison's methods. Few can afford to buy his books (just one book costs 47 pounds sterling or about Rs 1300) or attend the seminars. What we need here most urgently are systems that impoverished farmers can use easily, that can spread without the need of "graduates of a Permaculture Institute" or any other such body.

I get the uncomfortable feeling that Mollison is promoting an "environmental cult" (Permacult?), similar to evangelical cults, whose leaders are the sole beneficiaries from the business of preaching. A leaflet entitled "Permaculture", undated but probably issued in 1983, describes his work as "Design Consultancy". The consultancy is a world-wide association of independently-registered BUSINESSES, cooperating as a single entity of some 400 consultants in 1982. (emphasis added) Is commercialisation compatible with self-reliance and sustainability? Is it a new type of environmental colonialism? Do we need to encourage new forms of colonialism to mentally enslave ourselves?

Our traditional, sustainable agricultural practices are described in old books and journals and can still be observed in use among Adivasis and those who have not been corrupted by western culture. (Taken from, Winin Pereira, 'Permaculture or Permacult?', first published in 1990, revised in 1996).

Section II

Soil Fertility and Land Regeneration

Section editors: Bernard Declercq and Sultan Ismail

Philosophy must stand on firm ground. A living soil is one of the basics of organic farming. Working with unhealthy, dying or dead soils cannot be deemed organic farming under any circumstances. Even those farms interested in converting from chemical farming to organic will have to wait a period of conversion during which the soils killed or made sick by chemical farming methods are permitted to regenerate and recuperate their powers.

The condition of the soil, whether it is alive or dead, is of precious little concern in conventional farming. It is generally admitted that the chemicals and salts introduced into the soil through so-called modern methods turn the soil sterile: soil organisms perish; earthworms disappear; the soil becomes dead. On this dead substratum are our crops raised.

In the essays that follow in this section, Vandana Shiva speaks of the crisis of dying soils. The complex relationships between chemicals in the soil and plant activity are examined by Peter Tompkins and Christopher Bird who voice with concern the effects of destruction of soils by chemicals and other poisons.

Bernard Declercq next provides a detailed and graphic introduction to the preoccupation with soils in organic farming and proposes concrete measures for soil restoration using appropriate plant species.

In another fairly detailed essay, Claude Bourguignon provides a scintillating analysis of how plants actually function and the sources of their nutrition. He also proves the uselessness of chemicals for tropical agriculture and, like Albert Howard, urges us to imitate the forest system in its superb use of natural resources.

Finally, Sultan Ismail provides a compact and lucid introduction to vermicology, the art and science of maintaining earthworms in the soil and harnessing their activities for soil regeneration.

Recovering Our Dying Soils

By Vandana Shiva

The fertility of the earth is contained in the thin layer of topsoil which supports all plant life, and which is, in turn, protected by plants. The women of Chipko often describe their struggle as one aimed at protecting this "skin of the earth" which, when it is peeled off through erosion or damaged through loss of nutrients and moisture, leaves the earth wounded and diseased. Women tribals of Orissa sang Mati Devta Dharam Devta (the soil is our goddess, the soil is our faith) when they kissed the earth before being dragged away by the police in their struggle against the ruination of their sacred Gandhamardhan hill.

Today, the soils of India are dying, and the most fertile among them are dying because of the violence of green revolution technologies. The carefully evolved soil building strategies of women's work in organic agriculture have been disrupted overnight by western scientific arrogance which sees fertilizer factories as the only source of soil nutrients, and dams and large scale irrigation as the only source of plant moisture. As a study from Nepal states, "reports from field observations made by project researches indicate that in all the communities where chemical fertilizer is in common use, it is men who decide on and apply them, while women have almost the complete responsibility for preparation and application of organic manure".

Respecting the rights of the soil

We have had two decades of large-scale and rapid destruction of fertile agricultural soils in India as a result of the very processes which attempted to increase agricultural productivity. We have also had failed attempts at "technological fixes" to the problem of dying soils from the very agencies which designed the green revolution technologies. The solution to the crisis of dying soils cannot lie in the hands of those who first created the problem, who look only to the market, not to the life of the soil or the work of women as soil builders. The healing and recovery of soils will not emerge by continuing to cling to the market as an organising principle for agriculture. Recovery lies in rediscovering natural ways of renewal and learning, once again, to see that the soil has a right to a share of her produce in order to renew herself. Respecting that right is critical to satisfying our needs.

Under the assumption that nature is inefficient, we are rapidly undermining her productivity. The death of soils is just one among

many of the expressions of the arrogance which forces us to work *against* nature's productivity rather than build on it. There is a common misperception that a concern for nature's rights is to ignore people's rights, and that the sustainable use of soils goes against the demands for food for the hungry. Yet it is not satisfying the needs of the poor that has killed fertile soils through desertification and disease. Water-logging and salinity, micro-nutrient deficiency, toxicity and the depletion of organic matter are direct and inevitable consequences of a philosophy of agriculture guided by the modern patriarchal principle of profit-maximisation. The recovery of soils can only take place through a philosophy which sees soil fertility, not cash, as agricultural capital, which sees women, not fertilizer factories, as nutrient suppliers, and which puts nature and human needs, not markets, at the centre of sustainable agriculture and land use. If soils and people are to live, we must stop converting soil fertility into cash and productive lands into deserts.

Today, as western experts again flock to the Third World in search of instant solutions to the problem of dying soils, they often blame the victims—the woman, the tribal, the peasant. They forget that the "Dust Bowl" technology for the manufacture of deserts from fertile soils was first mastered in the colonisation of native Indian lands in North America by men of European culture, with European techniques—the intensive use of artificial fertilizers, extensive practice of monoculturing, and intensive and extensive mechanisation which turned the fertile grasslands of Oklahoma into a desert in less than thirty years. As Hyams observes:

Today it would probably be possible to turn the soil fertility of an area as large as the Dust Bowl into some other form of wealth, or into cash, in about ten years, with the aid of the enormously powerful machinery now available for self-fertility mining...When, between 1889 and 1900, thousands of farmers were settling Oklahoma, it must have seemed to them that they were founding a new agricultural civilization which might endure as long as Egypt. The grandsons, and even the sons of these settlers who so swiftly became a disease of their soil, trekked from their ruined farmsteads, their buried or uprooted crops, their dead soil, with the dust of their own making in their eyes and hair, the barren sand of a once fertile plain gritting between their teeth... The pitiful procession passed westward, an object of disgust--the God-dam'd Okies. But these God-dam'd Okies were the scapegoats of a generation, and the God who had damned them was perhaps, after all, a Goddess, her name Ceres, Demeter, Maia, or something older and more terrible. And what she damned them for was their corruption, their fundamental ignorance of the nature of her world, their defiance of the laws of cooperation and return which are the basis of life on this planet.

Since then, western patriarchy's highly energy-intensive, chemical-intensive, water-intensive and capital-intensive agricultural techniques for creating deserts out of fertile soils in less than one or two decades has spread rapidly across the Third World as agricultural development, accelerated by the green revolution and financed by international development and aid agencies.

The recovery of the soil as a living system needs the recovery of the feminine principle in agriculture, and with it a spirit of respect and care for the earth as caring and protective.

Chemicals, Plants and Man

By Peter Tompkins and Christopher Bird

In the pyramid of life, plants play an essential role. Man cannot ingest essential elements directly from the soil. They must be brought to him through the good graces of living plants, which likewise feed all animals, directly or indirectly. Whether it is through plant or animal our bodies grow out of the soil. Micro-organisms break up the chemicals and make them acceptable to plants. Plants can synthesize carbohydrates from the air, rainfall and sunshine. But before the life processes can convert these carbohydrates into amino acids and proteins, they must have help from a fertile soil. Neither man nor animal can synthesize the necessary proteins from the elements. Animals can only assemble them from the amino acids, providing the necessary kinds and amounts of each can be collected or produced by plants with the help of microbes.

Protein-producing plants demand a long list of elements from the soil: nitrogen, sulphur, and phosphorus are required to make part of the protein molecule; calcium and lime are also required; and magnesium, manganese, boron, copper, zinc, molybdenum, and other elements are needed in connection with protein construction, even if only in such small amounts as are called "trace". If the soil is not properly fertile, not teeming with micro-organisms, the whole process grinds to a halt. To keep the micro-organisms alive great quantities of decaying organic matter need to be added to the earth. On the forest floor dead plant matter and dead animal matter go back into the land. Leaf mould, through decay, continues to give life to the land, returning to the soil what the tree took as nutrient. Fertile soil is full of life and death; death and decay of organic matter; life in the form of bacteria, moulds and earthworms.

It should be obvious that soil is vital to health. Healthy soil, properly composted, with the right bacteria, fungi and earthworms, free from chemical fertilizers and pesticides, produces strong healthy plants which naturally repel pests. Healthy plants make strong healthy animals and strong healthy human beings. Poor land grows poor food, poor in vitamins, minerals, enzymes and proteins; this produces poor, sick people. Worn out land causes people to leave the farms and go to live in the slums.

It is a fact that plants grown on well balanced fertile soils have a natural immunity to insects and disease, just as a properly nourished body has an immunity to disease. Bugs and worms tend to gravitate towards plants which have grown on poor soil. One of the worst weakeners of plants turns out to be chemical fertilizer, or NPK, which came into general use on farms at the end of the Second World War. (Taken from *The Secret Life of Plants*. pp 225-6).

Simultaneous with the application of fertilizers, the chemical companies began to douse the land with chemical pesticides, abetted by the government and with the tacit support of university professors. Three hundred million pounds of different chemical poisons are now produced under twenty-two thousand different brand names, which result in the destruction of wild life and essential insect and microbe life. Of mass spraying, Dr George J. Wallace, Michigan University zoologist, went on the record to say that it "poses the greatest threat that animal life in North America has ever faced—worse than deforestation, worse than illegal shooting, worse than drainage, drought, oil pollution, possibly worse than all these decimating factors combined."

Not only wild life but fish in fresh water and even in the ocean are gradually being poisoned by a combination of insecticides and herbicides. Yet the DDT which wiped out fish and small game left its prime target, the boll weevil, flourishing. Despite the application of chemical pesticides the insects are gaining the upper hand, doing $4 billion worth of damage to crops each year. And no amount of argument appears to put over the fact that *healthy* crops are naturally pest resistant, keeping the insects at bay. In her book *Silent Spring*, Rachel Carson long ago made clear that the environment, which supports human life, is being strained to the point of collapse. (Taken from *The Secret Life of Plants*. pp 226-7).

Part I: Organic Farming and the Soil

By Bernard Declercq

> *One ought to be able to see how beautiful outward nature can be and usually is, although it is itself apparently "inconscient". Why should the growth of consciousness in inward Nature be attended by so much ugliness and evil spoiling the beauty of outward creation?*
>
> Sri Aurobindo

All is not well on the agricultural front. Misgivings are being felt and pronounced. The ill effects of chemical fertilizers are known to one and all. The media: TV, radio, magazines and newspapers are full with stories about the health hazards of pesticide use. Chemical molecules are invading our daily diet. Hundreds of different food items in colourful packages are being offered to the consumer, however the main ingredients used by the food processing industry are basically the same (e.g. soya or fruit pulp). Only a few plants or ingredients are transformed into various edibles using thousands of different chemical compounds! The additives used include colouring and discolouring agents, emulsifiers, aromas, flavours, binding agents, preservatives etc., and finally to make people eat all this stuff, taste enhancers. Recent studies have revealed the tremendous impact of the chemicals used in agriculture on the human immune system and fertility. But that's the way it is. It is inevitable...or...is there an alternative? Organic farming...maybe?

The current opinion is that organic farming is good, desirable even. It produces quality food without endangering the environment. It is very good for some who can afford it, but what about the common man? What about the growing population? Can organic farming feed the world? Will organic farming not take the nation back to the miseries of the past; famines, lethargy, ignorance? Is it scientific? Can one say that science and technology have not brought an immense progress in agriculture for the benefit of the people! Will biotechnology not once and for all end the miseries of our planet, mother earth?

These are the questions asked, the well intended and wise reflections and remarks made.

Some of these reactions might be based on partial information, or sheer ignorance of facts or they are but mere products of a conditioned mind that refuses to inquire. Nevertheless all these antagonistic remarks need to be addressed definitely.

The material before us is extensive and only a selection of it can

be presented here. The strongest testimony is of course the living experience of many organic farmers in the country. Their efforts and work are standing examples of the amazing potential of organic farming.

Forgotten Facts

First of all it must be mentioned that numerous small dryland and tribal farmers are even now cultivating in their own ways without resort to external inputs. They simply cannot afford to buy expensive chemical fertilizers even if they wish to. Also fertilizers have proven not to work very well on drylands. In fact this is one of the reasons why dryland farming was grossly neglected during the green revolution. The drylands have actually been adversely affected by it. Yet it is these very drylands that will have to feed the population in the immediate future.

And here looking at figures proves to be very disturbing. It has been estimated that within 35 years from now the population of India will double. Given that all these extra people also need houses, schools, hospitals, roads, offices etc. and space to live, a startling reality threatens to unfold. Knowing the present pattern, all these developments will take place on level lands with access to water and roads and around already overcrowded cities. The brunt of losing prime agricultural land to "development" will have to be borne by the lesser endowed drylands. It follows that these marginal drylands will have to produce a lot more. How much more? Some say 4 times more, maybe as much as 16 times more then today! And how are we going to accomplish this?

And this leads us to the second point, the *enormous* degradation and wastage of land.

While travelling through India either by bus, train, even by air, one notices large stretches of land laying waste, unused, barren. A huge land mass is given over to the destructive forces. Of the 226 million ha. available for cultivation in India, 175 million ha. is rapidly getting degraded! More then one third of the arable lands are wasted by water-logging, salinity, mining and erosion. World wide, 25.400 million tons of topsoil are either blown or washed away from farmers' fields. Actually more nutrients are lost due to this erosion every year than the whole chemical industry can produce!

We already know that the green revolution packages are sure to fail on these marginal soils. They have met with some success only in the fertile plains and deltas. Nevertheless we invest huge capital and energy in bioengineering, creating superman-like plants which must be able to grow in...what...a ruined soil, a devastated earth!? It

is like putting a plaster on a wooden leg. Why not heal the earth in the first place? It is not a question of breeding super hybrid strains of rice and wheat to meet the food demand but to reclaim those wasted lands, to arrest all further destruction of the nourishing earth. Let us leave the chemicals in their bottles and stop the slicing of genes. Let us care for the land again. The earth is not in need of technical devices but of love.

By clever design with small water-harvesting ponds and multi-purpose trees, native seeds, a cow and a few ducks, recycling of bio-mass, small farmers caring for the land, all this can change wasted lands into productive, sustainable little wonders.

But agricultural policies do not favour small self sufficient farms. They favour corporate farming, business farming, not health, progress and happiness, but domination, greed, and exploitation.

Questioning the Basics of Chemical Agriculture

> *"One perceives the fundamental essence of life in the living, not in the inanimate, in that which is changing, not in what is finished."*
>
> Goethe

Modern scientific or rather chemical farming has as its starting point the work of Baron Justus von Liebig. He took a plant, burned it (alive) and tried to read the secrets of plant life in the remaining ashes. In his essay, "Chemistry in its Application to Agriculture and Physiology" published in 1840, he stated that everything required by living plants is found in the mineral salts contained in their ashes. By adding these chemical salts to the soil, plants could be made to grow better, bigger and fatter.

In one stroke millennia of empirical observations by farmers and savants alike about the fundamental role of humus was brushed aside. Soil was finally known to be an inert physical support for plants to grow in (so that they do not fall over when they grow maybe). Needless to say, the chemical factories were very happy to hear such stories. But what is crucial to understand is that the fundament of chemical farming is built on the ashes of a dead plant. What is true for a dead plant might not be true for a living one. And farmers grow living plants in a soil that teems with life! It has been proven time and again that living plants do not necessarily follow the class rules of the chemistry teachers.

In the famous research station of Rothamsted for instance, researchers cropped a field to clover continuously for 17 years. No fertilizers whatsoever were added at any given time. The clover was cut

regularly, weighed and analyzed. It was found that in those 17 years the clover had removed more than 10 tons of magnesium, potash, phosphoric acid, etc., combined. The clover, according to the detailed soil tests made, seemed to have extracted more elements than the soil actually contained! Where did all these minerals come from?

Other researchers did germination tests under strict controlled conditions. They found that seeds sprouted in distilled water in lab conditions seemed to contain more potassium, magnesium or phosphorus than was present in the seed! This leads us to conclude that life is very complex and unpredictable and there is much in the life of plants that we do not yet understand.

Albrecht von Herzeele (1873), Pierre Baranger (1958), Louis Kervran (1962) and many others proved beyond refute that living plants growing in a living soil have very particular strategies at their disposal with which they seem to *create* the needed elements in short supply from those which are more abundantly available. Louis Kervran, one of the greatest scientists of modern France and one of the harshest critics of conventional agricultural science wrote:

"Classical agriculture (the science that is taught in schools) is a huge imposture which is frightening in its cynicism. It recommends the use of "complete" fertilizers (N.P.K.) as if these three elements were the only ones to be found in plants." (Kevran 1972)

Indeed how can it be explained that by adding only 3 elements and of course a substantial dose of toxic plant protection substances, crops can grow year after year providing us with bumper yields? Especially since we know that plants contain not 3 but 34 elements (some sources quote more than 60!) which are essential for their metabolism and growth. Either they mine the soil or these vital components are not present in crop yields anymore...or plants have their own chemistry departments!

Studying the removal of zinc and other elements from oat fields, Kervran further wrote: *"Not all these elements however, exist in the soil in such quantities...It must be established whether or not the soil contains elements that the plants will utilize to fix other elements not found in the soil which are necessary for its growth. Conditions must allow the transmutations to take place. These usually take place in the presence of micro-organisms for which the rhizome must provide the conditions for a vigorous proliferation." (Kevran, 1972)*

He finally concluded that *"we must have a synthesis of a biological agriculture which is far removed from 'classical agriculture' concerned only with providing N, P and K."*

A very interesting anecdote worth mentioning here is that at the same time Von Liebig was starting his chemical industry, another German agronomist, Julius Hensel came up with a very different

approach (1893). Julius Hensel provided plants with fine ground rock dust powder, which he considered the aboriginal food for the plant-micro-organism combine, and obtained growth and yields much better than with the more costly chemical salts of Von Liebig. Soon he became very popular with the farming community. Even the Grand Duke of Luxemburg opted for Hensel's method in his large estates. The results as verified by a group of evaluators were extraordinary, much better than in the neighbouring field where the chemicals were used. However at that time no "scientific" (chemical) explanation was found for Hensel's methods and he was blacklisted, drawn before the court of justice and in spite of hundreds of farmers testifying in his favour, he was sidelined. The chemical industry and its profiteers had become powerful already. His books were kept out of print. Even the royalty could not stand up anymore against the "vested interests". Hensel was declared a heretic and later his books were burnt!

Biotechnology?

Though since long Liebig's assumptions have been refuted and enormous progress has been made to really understand the complex process of the growth of plants, these are still considered as one dimensional and insentient and hence studied as such. At best plants are studied as individual specimen grown under artificial conditions which are far removed from their natural environment. It is unfortunate that this mentality still dominates today and that certain scientists locked up in their NPK mentality refuse to see the connection between this limited and thus defective approach and the present day ecological and agricultural disasters. To say it with the words of Teruo Higa:

"The current agricultural technology is a system which is dominated by approaches of symptomatic therapy and which requires chemical fertilisers and pesticides. The largest mistake of this system is that it is based on inorganic chemistry and that it does not consider organic chemistry and vital phenomena in the soil. Such a system is the cause of the vicious circle threatening the existence of mankind." But we do not seem to learn from mistakes, on the contrary, more of the same is pushed upon the living world in the form of biotechnology. It is like "rearranging the chairs on the deck of Titanic".

Biotechnology, an advanced science, seems ignorant of the fact that all life forms are closely interlinked and interact within the sacred body of the natural world. Plants and micro-organisms have a reciprocal action upon each other. Nobody can say what will happen to the soil micro-organisms when transgenic crops are grown. Field trials have already shown that herbicide resistance transgenes can spread to weedy relatives in the unbelievable short time span of just

one growing season. *Even when* as in the case of vector mediated gene transfer, the mobility genes are deleted, nothing can prevent these vectors to associate with naturally occurring parasitic genetic elements which can jump in and out of the host cells. There will further be ample opportunity, so continues Mae-Wan-Ho, for the genetic elements to recombine with viruses and bacteria to generate new possible pathogenic strains (which of course will be resistant to antibiotics). The real danger of bio-technology is that the *same* ash or dead mentality continues, but with another dimension where even a little mishap can have disproportionately disastrous results. Can the problems of agriculture and existence be solved with the same state of consciousness which created the problems in the first place? Biotechnology seems to have forgotten that crops grow on the land, in the soil and that land degradation and soil destruction could well be the ultimate limiting factor.

For organic farmers the so called genetic material is an instrument for ensuring the fixed habits of plant to express certain characteristics in tune with the prevalent environmental conditions. This environmental factors include soil and soil life, the other plants, location and weather, etc., the whole ecosystem and its dynamic force. In the case of domesticated plants this includes man. All this factors will influence the growth and performance of plants.

Scent in fine rices depends much on the location, the quality of the irrigation water, the weather, agronomic practices and on the farmer.

The stature of the plant, whether tall and slender or short and sturdy or the size and position of the leaves of a plant depends a lot on the quality of the soil and the root development, the type of soil preparation, spacing and on agronomic practices.

Disease resistance depends for a very large part on soil microorganisms, weather, the presence of other plants, the life force of a given milieu, the balance in the living world around the plant and the condition of the farmer!

These are well established empirical observations by farmers and gardeners of all times in all countries and climes.

Fortunately there are scholars who have not been misled by this one dimensional outlook on the plant world. Albert Howard, Ehrenfried Pfeiffer, H.P. Rusch, Claude Bourguignon and many more whose work is not even mentioned in the curriculum of the agricultural universities.

Yes, science has contributed to the unfolding of agriculture. The question is, which science? Not necessarily the one taught in our agricultural schools.

This is what Von Liebig at the end of his life had to say:

"I have sinned against the wisdom of the creator and received my righteous punishment. I wished to improve his work and in my blindness believed that, in the marvelous chain of laws binding life on earth's surface and keeping it always new, a link had been forgotten which I weak and powerless worm must supply."

Agricultural Planning and Policies

Agricultural planning and policies are not better off. As the result of the ill planned strategies of the green revolution food production is concentrated in a few districts in each state, near rivers and dams. But while food production staggers or falls back, population grows exponentially. Planners and policy makers usually see large sustainable agricultural enterprises, efficiently working with sophisticated machinery as the ultimate solution. Larger farms are *not* energy efficient and this might be of importance in the future. Neither are large farms very productive.

In an industrial monoculture, 300 units of inputs are used to produce 100 units of food, thus having a productivity of 0.33. In a polyculture system, 5 units of inputs are used to produce 100 units of food, thus having a productivity of 20! (Scientific American). Even the World Development Report (WDR) has accepted that small farms are more productive than large ones. This is very clear from the example of West Bengal. As a result of the land reform there, agricultural growth was 6.5% while the rate for the rest of India was only 3%. Furthermore, large farms working with labour saving machinery, would bring down the number of people working in agriculture and increase joblessness considerably.

Conventional agriculture has, in a short time, reaped the fertility built up over the ages by traditional farmers. By mining the soil or raping virgin lands, it has built huge food reserves. It has even produced huge excesses which cost a lot of money to be destroyed. All this was paid by the forests which were cut, the soil which sacrificed its life, the rivers which dried up, the ground water table which withdrew to the depths. Yes, the harvests were great, so was the price paid. Dead lakes, poisoned drinking water, barren minds.

And now the go-downs are at a record low. And the food stored is used as an economic-political weapon more than for feeding the needy and the environmental refugees.

Still, it could be argued that the past traditional farming was worse. Remember those famines...?

Traditional Farming, an Example of Sustainability?

The past can feed the future.

Ileia.

There are impressions about the past and there are also recorded facts. Let us look at these. The descriptions of rural scenes by the Chinese travelers Fa Hien (5th century A.D.) and Huang Tsang (7th century A.D.) or by Mr. Le Tavernier (18th century A.D.) about the marvel and opulence of India might be coloured with romanticism, though temple inscriptions in South India seem to confirm their view. From these inscriptions (9th to 12th century A.D.) it appears that rice yields for instance were remarkable. They mention yields in Tanjavur from 12 to 18 tons per hectare, in Coimbatore 13 tons and in South Arcot 14.5 tons per hectare! Many reports by British officials like A. Walker (1820) and Dr J.A. Voelcker (1893) or figures found in other official documents, equally point to these surprising facts.

In the 18th century (around 1770), Thomas Barnard, a British engineer, conducted a survey in Chengalpattu district near Madras covering 800 villages. The results show the average yield of wetland rice to be 3600 kg/ha and 1600 kg/ha for dryland rice. In 130 villages the average yield for wetland rice was 8200 kg/ha. In many villages out of these, yields surpassed 10,000 kg/ha (the present day average is 3177 kg/ha).

In 1873, after the opening of the Suez canal the first wheat shipped from India arrived in England. The British envisaged India as a potentially secure source of wheat for the Empire.

Though much rice and wheat were exported, domestic availability grew at about the same rate (George Blyn/*India's Crop Output Trends, Past and Present*).

The export of food grains rose from £8,58,000 in 1849 to 19.3 million in 1914. Oil seeds export increased from 2 million to the staggering figure of 5 million in a period of 19 years. A considerable increase in output this is. Modern agriculture, less then a century old, could be a little more modest in its claims.

During the time of the last ruler of Bengal (1764-65), the revenue of the land was £817,000. In the first year of the East India Company the revenue rose to £1,470,000.

And what follows was written by Warren Hastings in *1772* a year after the great famine of Bengal: "Not withstanding the loss of at least 1/3 of the inhabitants of the province (Bengal) and the consequent decrease of the cultivation, the net collection of the year 1771 exceeded even those of 1768...It was naturally to be expected that the

diminution of revenue should have kept an equal pace with the other consequences of so great a calamity. That it did not, was owing to its being violently kept up to its former standard." (*PPST*, Nov. 82)

In 1793 Lord Cornwallis fixed the revenue of the land to the amount of £3,400,000.

When Dr. Wallick addressed a committee of the British House of Commons in 1832, the following question was asked: *"Whether Indian agriculture was susceptible to any great improvement."* The answer is quite revealing:

"Certainly, but not to so great an extent as is generally imagined; for instance, in rice cultivation, I should think if we were to live for another thousand years, we should hardly see any improvement in that branch of cultivation." (PPST Nov. 82).

The sophistication of Indian agriculture then was considerably beyond the comprehension of the British administrators of the 18th century. The British found seed drills and farming technologies like cropping cereals with legumes, which they most likely took back home stopping in this way their very own food shortages.

These are just plain facts. It shows that we live with distorted impressions. But how do we explain the poverty and the famines?

In 1750 the farmer had to pay for every 1000 units of produce, 300 units as tax, out of which only 50 units went to the Central Authority, the rest remained in the locality. But in 1830 the farmer had to give away 650 units as revenue, 590 of which went straight to the Central Authority.

These figures help to explain the poverty of the peasantry—the 24 famines in the latter part of the 19th century with a total of 20 million victims. And what could indeed be a better explanation for the famines than the simple "fact" that Indian agriculture was primitive, backward and unscientific?

The "improvements" sought after were—how to make Indian peasants grow cotton and Indigo and other cash crops for the palate of the hungry European industries and for the elite!

In the course of time, the forests, public lands and water bodies became government property. The farmers had to rob the resources they had so nicely maintained for centuries. Under pressure of such incredible exploitation, traditional farming crashed. Yields plummeted to abysmal lows—one ton per hectare—around and after independence. What the village farmers are practicing today is necessarily a very diminished version of what was once a remarkable farming system.

So by looking at these facts and figures a very different picture emerges.

But the past is good where it belongs...in the past. There is no return even for those who wish to. What we need to remember and keep for our future evolution, is *that* reverence for life, that resilient spirit and the essence of its knowledge—the understanding that all is interconnected, the living and the inert. But foremost, that the earth is sacred, that nature is the matrix. The farmer is a co-creator in her unfolding process. To be attuned to nature is to prosper, to go against her will end in ruin.

Part II: The Real Needs of Plants

Plant Nutrition

When we say "farming", we really talk about the growing of plants for our food. To know about plants the way they are, live and grow are thus the things we need to understand.

For that we should first look at the figures on the nutrition of plants in the table below:

I.	**Elements from the Atmosphere** They represent 95 to 98% of a plant's dry weight. Vital elements all constitutive: *carbon, oxygen, hydrogen, nitrogen.*
II.	**Elements from the Soil** They represent 2-5% of a plants' dry weight. 12 vital elements: 2 non-constitutive: *potassium and chlorine;* and 10 constitutive: *phosphorus, boron, calcium, magnesium, sulfur, iron, manganese, molybdenum, copper, zinc.* 18 trace-elements: 4 non-constitutive: *lithium, sodium, rubidium, cesium;* and 14 constitutive: *fluorine, silicon, selenium, cobalt, iodine, strontium, barium, aluminum, vanadium, tin, nickel, chromium, beryllium, bromine.*

Tab. 1: Claude Bourguignon: *Le Sol, La Terre et les Champs.*

The above table shows us that plants feed themselves in two distinct ways, from the atmosphere and from the soil. Elements taken from the atmosphere are; carbon 44%, oxygen 44%, hydrogen 6% and nitrogen (via the microbial world) 2 or 3%. It thus appears that the bulk of a plants food is taken from the air. It is easily available for plants and there is plenty of it. It also appears that we have a lot to do to control pollution.

The balance, a mere 5% of a plant's diet, comes from the soil. This consists of small quantities of various minerals. We can thus

conclude that plants feed quantitatively from the atmosphere and qualitatively from the soil. To feed plants quantitatively from the soil as is being done in conventional agriculture, is thus going against their physiology.

The elements taken from the soil are of two kinds, constitutive and non-constitutive of plant matter. The constitutive elements are absorbed by plants either in an oxidised or chelated way. These transformations are brought about by the microorganisms of the soil.

The non-constitutive elements (e.g. potassium, lithium, etc.) are borrowed from the soil, so to say, and simply provide the plants with electric charges needed for their various growth processes. These elements are returned to the soil at the maturity stage. Only green plants and other living parts such as the seeds, contain minute quantities of these elements.

It thus appears that all constitutive elements pass through the biological cycle and are thus entering the plants in an organic way. The only elements to enter plants in an atomic way are not constitutive of plant matter. Plants have thus an organic diet.

A small practical example illustrates well where we stand. A crop of rice at an average of 2 tons per acre consists of 1900 kg. of air (elements from the atmosphere) and of 100 kg. of soil (elements taken from the soil). One of the elements taken from the soil by the rice plant is zinc, at about 8 ppm. However in conventional farming the prescription is to apply 12 kg. of zinc sulphate to the acre! (Plumbers or farmers that's the question). The conclusion is that conventional farming promotes odd practises that go against the nature of the plants or are aimed not at enriching the soil but at enriching...others.

We can thus see very clearly that plants feed organically from the soil. These facts and this knowledge allows us to set aside, once and for all, the notion that *plants have mainly or purely a mineral diet*!

Overcoming Soil Deficiencies—Nature's Way

The soil contains most of the nutrients needed by plants. There are exceptional cases wherein soils may be naturally deficient in one mineral or the other but this is a rare phenomenon. Nature usually corrects herself, by growing accumulator plants for instance. Wild thistles seem to thrive in soils deficient in phosphorus, potassium and selenium, though on analysis we find that thistles have a high content of these minerals! Mushrooms accumulate zinc! Thus for zinc in rice fields think of wild mushrooms. By growing accumulator plants as a green manure or associated with the crops, we can assist

nature in recreating a balance. Of course a farmer cannot always wait until his soil has regained balance. Hence it might be necessary to add rock powders containing the element in short supply. Another way to overcome deficiencies is to collect leaves of various plants, young leaves , mature leaves and old leaves, compost them and apply in small quantities to plants. Or else simply buy a little of the mineral from a drug store and add it to the compost pile. The fact however is that the deficiencies are usually brought about either by wrong fertilization or wrong cultivating methods like mono-cropping or by using hard chemicals that kill the micro-organisms. In no way does it mean that this or that element is, as such, lacking in the soil but that there are no soluble forms of it available.

In fact the core of the question of farming is to find out *how to stimulate and enlarge the microbial population in our soils.*

To come back to the elements from the soil, how they are taken up by plants and in what quantities, let us take a look at table 2 alongside.

Conclusion, we can see that most soils contain enough elements to provide us with bountiful and nourishing food.

Is it not strange that farmers are advised to apply up to 12 kg. of zinc per acre for rice? Agricultural science could study the factor that make for a high quality of agricultural soils. High quality and high productive soils can still be found in the natural state. We need to protect at all cost whatever remains of these natural margins. To study their agricultural methodology and to learn how all problems of agriculture have already found a solution there, is what is truly needed.

Element	**% of dry matter**	**Manner of uptake**	**Origin**
			I. ATMOSPHERE
Carbon	44	Photo-synthesis	Carbonic gas from air
Oxygen	44	Photo-synthesis	Carbonic gas & water
Hydrogen	6	Photo-decomposition	Rain water
Nitrogen	1 - 4	Biological fixation by microbes of the soil	Nitrogen gas from the air

Element	% of dry matter	Manner of uptake	Origin
			II. SOIL
Potassium	0.1 - 2.5	Element "on loan" from the soil solution and returned to the soil at the end of the plant's life cycle.	From the mother rock reserves20-80 t/ha. Potassium from the microflora reser-ves up to 60 kg/ha.
Calcium	0.1 - 3	Acid Soils: Decomposition of the mother rock by climate, roots & microbes. Alkaline soils: Decarbonation of mo-ther rock by microbes	Calcium from the mother rock reserves 15-1200 t/ha. Calcium from humus reserves 300 kg-3t/ha.
Magnesium	0.1 - 0.9	Chelation or oxida-tion of magnesium by microbes.	Magnesium of the mother rock reserves 300 kg-3 t/ha.
Phosphorus	0.1 - 0.9	From the mother rock: oxidation by soil microbes. Liberated from humus by soil microbes. From clay particles by micorrhiza filaments which recover retrograde phosphates.	Phosphorus from the mother rock reserves 600 kg-15 t/ha. Phosphorus from humus reserves 150 kg-1.5 t/ha.
Sulfur	0.1 - 0.5	Mother rock: oxidation by soil microbes. Mineralisation of the humus by soil microbes.	From mother rock reserves 300-900 kg/ha. From humus reserves 120 kg-1.2 t/ha. From atmosph-eric pollution possible 10-100 kg/ha coming through the leaves as SO_2.
Chlorine	0.01 - 0.9	Element "on loan" from the soil solution and returned to the soil at the end of the plant's life cycle.	From mother rock reserves 300-600 kg/ ha. Cl from the world of microorganisms reserves 30-60 kg/ha.
Iron	500 ppm	Mother rock: chelation by soil microbes. Liberation of organic iron from the humus.	From the mother rock reserves 20-300 kg/ha. From humus reservs 3-15 kg/ha.

Element	% of dry matter	Manner of uptake	Origin
Boron	500 ppm	Mother rock: chelation by soil microbes. Liberation of organic boron from humus.	From the mother rock reserves 12-300 kg/ha. From humus reserves 3-15 kg/ha.
Manganese	500 ppm	Mother rock: chelation by soil microbes. Liberation of organic Mn from the humus.	From the mother rock reserves 300 kg-15 t/ha. From humus reserves 3-15 kg/ha.
Copper	20 ppm	Mother rock: chelation by soil microbes. Liberation of organic copper by soil microbes from the humus.	From the mother rock reserves 3-300 kg/ha. From humus reserves 1-5 kg/ha.
Zinc	20 ppm	Mother rock: chelation by soil microbes. Liberation of organic zinc by soil microbes from the humus.	From the mother rock reserves 30-1500 kg/ha. From humus reserves 1-2 kg/ha.
Molybdenum	1 ppm	Mother rock: chelation by microbes. Liberation by soil microbes from the humus.	From mother rock reserves 3-30 kg/ha. From humus reserves ± 1 kg/ha.

The Elements

Let us look at plants from another angle. All things in the universe including plants, it is said, are composed of the five elements. We can also say that the plants harvest the sun's energy, and that our main concern is to understand how to transform the sun's energy into an edible form! We are leaving aside all arguments on other subtle or cosmic energies, though there is a lot to be said there.

In a certain sense, all that is needed for farming are the 5 elements: soil, water light (heat) air and ether. As long as these elements are present we will be able to practice farming. There is no need to add or invent new ones. Let us have a closer look at these elements:

Ether – Sound

The original oneness, the sheath out of which the others manifest.

Air – Sound + Contact

You cannot touch the air, but it can touch you! It is the carrier of *prana.*

Light (heat & fire) – Sound + Contact + Form

The sun represents the active energy which makes plants grow.

Water – Sound + Contact + Form + Taste

Water is the driving force of all nature.

Soil – Sound + Contact + Form + Taste + Smell

The basis, materia prima, the beginning and fulfillment.

Let us see how each one of these elements is of prime importance for the growth of plants. We will start with air as it forms the bulk of a plant's diet, and thus of ours too.

Air

Air is an entity with many qualities. It stores information and carries our intuitions (*'it's in the air'*). The air is the treasure-house of dreams and boundless imagination, the inspiration of poets and philosophers.

A particular smell or quality of air can remind us of the hot plains in summer or of the forests on the Western Ghats. Air is the vehicle of *prana*. Air is absolutely necessary for anything to thrive. Everyone knows the healing and purifying quality of the air (mountain air for instance). It can alleviate our psychological stresses. The air is pregnant with many possibilities not yet manifested.

"Take a change of Air." Before you do so, remember what we said earlier, plants constantly "*eat*" air. And what are we doing to the air? We are making great efforts, at a gigantic expense, to change the chemical composition of the air (pollution). Of course, we do not have the slightest idea about how this could influence and affect all forms of life on this planet.

Even in the soil, air is an ingredient of major importance. It is in the pores, the spaces, the small air pockets, that gases and water circulate. Since air is so important for plants (Carbon 44%, Oxygen 44%, Hydrogen 6% via water, Nitrogen 0.4 to 4% via micro-organisms), how can we work upon this element in our garden and fields?

Physically it means working with windbreaks, spacing and multi -tier planting. Strong air movements, that is, wind can damage the leaves and so affect a plant's food intake, or prevent them from "eating". Stale air induces ill-health in plants. In rice fields farmers walk

between the rows pushing the plant aside so that air can better penetrate. Hedges grown along with crops in the form of alleys can protect the crops from strong winds.

Light – Heat

Light is a factor of change. Someone on whom "the light has dawned" is a changed person. He starts to think differently, acts differently. Seeds are offered to the sunlight before sowing. Plants are very sensitive to light. Some plants are sun lovers, others prefer the shade. Some like a bit of both. Certain plants like to sprout in the shade, others prefer the sun. In temperate countries trees will not be duped by a too mild winter. They will run out only if the daylength increases. At night, the flashlight from a camera can trigger the flowering of citrus trees. The sunlight is the main source of energy for plants. This energy is used for growth and fruiting. If we can control the growth we can influence the fruiting.

Trees with a light, open crown like Sesbania grandiflora planted at 4 meters distance will create a light filter of 25%. This has its importance for instance if we want to cultivate delicate vegetables in the hot tropics. It can extend the growing season by several weeks. By planting in the direction of the sun, we can influence the light factor for the benefit of plants. Light and heat can be trapped by planting hedges on the Northern side.

Water reflects light and that has its importance in rice fields. Cellophane foil put under or near to fruit trees mirrors back the sunlight to the underside of the leaves, where the insects hide. This upsets them greatly, they start moving and get completely confused.

It is better not to irrigate the fields in the heat of the day but instead in the evening or better still, at night in the moon light. Keep a bucket of water in the sun and after cooling use it to water pot plants in the evening. In colder climates the use of sheet compost helps the soil keep up a good temperature necessary for the microorganisms to remain fully active. In the hot tropics, the mulch layer keeps the soil cool, moist and alive.

Water

Water is a compromise between fixity-solidity (e.g. mineral matter) and volatility (e.g. air, gas, vapour). Water manifests itself only when the necessary conditions are fulfilled—H_2O, etc.

Our relationship with water has changed drastically over the centuries. It is for us now a 'normal' event to have water at our immediate disposal—just switch on the pump and turn the tap on. Ear-

lier, fetching and carrying water—as is still practiced by a great part of the world's population—involved great labour. It brought people in contact with the sources of water. In the early times, religious homage was paid to water. Men regarded water as a divinity, a being with great strength and vigour, to be revered. Today we think of it as a commodity, a mere substance—H_2O. We have lost the knowledge and the experience of the subtle, the other, the "spiritual" nature of water. Even those who still fetch water daily from the well have been contaminated by this profane, one-dimensional view.

Gone are the days when water was a carrier of divine messages, a carrier of good luck and fortune.

Who among us is still sitting by the river side lending an ear to the communications from the beyond, in the murmurings of the living water? (Try the river Cooum in Chennai!)

The more we learn about the physical nature of water, the more we look at its physical value and learn how to use it technically, the more we become ignorant of the "being" of water and our knowledge of the soul and spirit of this element is fading. We have conquered and subdued water. We look at it rationally, scientifically. We discard all that cosmic "humbug" about the "being" of water as superstitious folly. Unfortunately in doing so, we not only lose touch with the spiritual value of water, but are actually loosing its very physical substance. The dying of springs, the drying up of whole rivers all over the world, is a symptom of this "development".

India is a very wet place! We have an average rainfall of 1170 mm. per year. The Mid West in the USA., the so-called bread basket of the world gets much less rainfall! Compare the rainfall figures of India with those elsewhere.

India	1170 mm annum
South America	550 mm annum
North America	808 mm annum
Europe	769 mm annum
Africa	725 mm annum
Asia	630 mm annum
Australia	456 mm annum

Unfortunately we are squandering our own resources. By the year 2000 we will have 20% less water then we had in 1983. Almost 50% of our rainfall runs off carrying the life sustaining soil with it. It is true that our rainfall comes pouring down within a few rainy days in the monsoon season. These downpours increasingly act as a source

of destruction rather than anything else—thanks to the mindless "rational" interference in the simple natural cycle and behavior of water.

What can we do to improve water availability for our plants? *This is the right question to reflect upon since plants consist of 80% water!*

Water conservation measures such as bunding and waterharvesting are a must for good farming. The addition of a good clay to a sandy or rocky soil will definitely increase the water holding capacity of the soil and the ion exchange capacity as well. The judicious use of water for irrigation is another important point. Plants need much less water then we assume. A common rule is to keep the root zone moist. Heavy watering leaches out vital nutrients from the soil. It can lead to all kinds of problems like salinity for instance. Alternate row irrigation will, for instance, save 50% water, reduce losses through leaching, and prevent a lot of trouble with pest and diseases. Mulching can easily be practiced in orchards, vegetable gardening and in row crops. To irrigate use water of ambivalent temperature. The best thing to do is to irrigate at night in the moonlight. Of course, a sustainable agriculture cannot rely on irrigation alone, especially with ground water or water from big dams. Water harvesting in farm ponds and life saving or protective irrigation at the critical stages of plant growth, are the ways for the future.

Planting of wind breaks will also help in preventing evaporation. Suitable species of shrubs and trees, that is, species with little root interference must be used. Care must be taken when planting wind breaks as in some cases it might even increase wind turbulence and thereby enhance evaporation. The wind break should not form a wall so to speak. Planting hedges in fields, at four meter intervals will also be very beneficial. Certain plants like Sesbania grandiflora cast a filtered shade on the soil and plants. This again helps in preventing evaporation and has many other beneficial effects as well.

Soil

Mother Earth
Store of Wisdom.

The soil is the fruit of a synergy between the mother rock and humus. It is the touch stone. Our dreams have to stand up to the reality of this nether element. Otherwise they remain where they are—in the air. The soil, matter, the body have always been rejected. It is the obstacle, the unwilling, rigid and unyielding element. In hydroponics we have even tried to do away with the soil. But look at the beauty of the mountains and the valleys. It is as if an ethereal dream has taken up a material body.

Strangely enough, though the soil is the source of our daily food, it remains an unknown, incomprehensible entity. Even scientifically so little is known about the soil's body and its various processes. In this obscure aspect of mother earth a constant miracle is at work. Here the "inanimate" inert matter becomes part of the living world.

The soil is thus a living organism, born out of a colloidal affair between clay and humus. It reaches maturity, it can become sick and it dies. It is very sick and dying today! When it is dead we call it erosion. Then the dead body of the soil is carried away by the winds and waters, to its final resting place, the ocean floor. Now more then ever, if our will is to continue to live on this planet, we will have to listen, to understand and to respect the soul of the soil. If there are still have doubts about soil life it would be interesting to know that 1 gram of soil contains between 10 million to 1 billion inhabitants (micro organisms)!

How can we work upon the soil element? Ignored by most of us, including agriculturists, is the fact that the most important part of a soil is air! It is in the pores and spaces that gasses and water circulate. A well structured soil has adequate air and so roots can easily penetrate it. The question then is—*how can we improve the air element in a soil?* Sub-soiling, the use of deep rooted plants earthworms and termites, all macro and micro fauna and flora will help to improve the air circulation of a soil. Now the question has evolved into—*what can be done to attract earthworms, termites and to stimulate soil life?*

We can breed the endemic earthworms separately and introduce them to our soils again. We can produce composts and use bio-fertilizers. But all living organisms need a proper environment and a source of food. This leads us to such practices as mulching, green manuring and again composting. If we do all this, in addition to proper crop combinations and a system of crop rotation, a "living" soil is bound to develop.

We can see that everything is interlinked. For instance, the practice of mulching will keep the soil cool and prevent water loss through evaporation. It will attract termites and earthworms who will make tunnels, allowing air to penetrate the soil and enhancing water percolation. This in turn will enhance other soil life indispensable for plants. The mulch ultimately decomposes and enriches the soil. Once the soil gets better aerated through all these processes, roots can penetrate the soil more easily and more deeply, giving them better access to subsoil moisture, and additionally, capillary action is improved. When plants can develop their full root system, their metabolism is strengthened and they are much better equipped to fight off pests, diseases and water stresses.

Indeed all what we have learned above cannot be separated and brought under various headings. But we are limited by our means of expression—we cannot talk simultaneously about two or more things at the same time!

A soil might be acidic or alkaline or have other problems, usually man made. Soil mixing is an old and useful practice. When a soil is too acid we can mix marl or limestone powder; in fact any natural source of calcium will do—crushed egg shells or dolomite for instance. If a soil is very sandy and has low fertility and water holding capacity, we can add a good clay, bentonite, for instance, or a black cotton soil rich in montmorilonnites. On the other hand if a soil is too clayey we can bring in some sand or if the clay soil is too alkaline we can mix red laterite soil to bring the pH. down. There are many known soil amendments which can be made to improve a given soil. As mentioned earlier cheaply available rock powders can be used. First we can do some pot tests, using a few spoons of the rock dust and a little compost (micro-organisms), to see if this particular amendment will suit our soil.

Soil development always consists of two interacting parts—soil conservation and soil regeneration. We do not want to conserve "bad" soil! To construct bunds, ridges, swales or trenches will conserve soil and moisture. Hedges, suitable trees and soil covers will further protect the soil against the elements, pump up nutrients from the subsoil and a regeneration process can start. If the soil is a living organism, then what applies to other living organisms applies equally to the soil.

Ether

Ether is the subtle element. It is the energy within things. Through the ether, the energy within us, we can communicate with the energy within plants. When we eat plants or anything else for that matter, besides the mere material substances (minerals, vitamins, etc.) we also imbibe the subtle (or gross) life force or energy, which can affect our body and mind. In our daily interactions with plants, water, air and soil, ether translates itself in the form of understanding, care and love, the perception of sacredness and of respect for all forms of life. Better yield are obtained when at the time of harvesting the fruit we "explain" to the plant our intention and need. But the subtle element has been denied existence by modern science. It cannot be measured, weighed or grasped by our physical senses.

If it is true that material phenomena must be verified by physical means, by our physical senses, then equally non-material phenomena must be comprehended by non-material means. And maybe,

after all, here also as in so many cases, the extremes may touch and matter and non-matter may be but different manifestations of the same "third" position.

It is known since the early times of agriculture that man's inner attitude has an influence on plants. Everywhere on earth you find the perception of the "green hand" or the "green thumb". In parts of Tamil Nadu this is determined by asking the young women to sow each a few lines of a given crop. The growth of the plants, etc. are carefully observed by the elders and then the green hand is identified. Through an understanding of the deeper nature of plants, we will be able to give them an ideal environment for their development. Indeed care and attention for plants are inputs that are most neglected. Available for free, yet refused!

The experiments of Backster and Jagdish Chandra Bose and many others have proved beyond recall this subtle being of plants, their response to mind waves and human feelings. Patients under the stress of modern living are "prescribed" to start a vegetable garden and care for plants.

We need to understand the personality of a plant, be sensitive to its preferences and dislikes, its natural way of being. For instance tomatoes love onions and marigolds but do not like beet root or fennel. Beans like carrots but cannot stand onions. Maize, cucumber and beans all grow happily together.

Trees for instance are like umbrellas. Everyone runs for the nearest tree when a thunder shower surprises us. A tree's canopy directs the water to the drip line, a straight vertical line connecting the edge of the canopy to the ground below. And right there we find the thirsty feeding roots. Again the bigger roots near the trunk push the earth upwards, showing us that the tree does not want its trunk to stand in the water. But when we irrigate we create basins around the trunk of the trees. How much do we sin against these simple rules and then complain that something or the other goes wrong. We must thus take these observations into account when we think of watering plants and trees.

Equally, the position of the moon or other cosmic influences are known since ages to affect plants. Sowing two days before full moon is said to be the ideal time. Bamboo and timber trees are cut with the descending moon, when sap flow is reduced.

There is a whole world to discover, once you start caring for plants. Observing quietly, the life and growth of plants in an undisturbed environment and learning from them—this is the only discipline we need to follow.

A positive sign is that some progressive scientists have now started examining this intriguing subject, though old as the hills, called phyto sociology.

Part III: The Reclamation of Wastelands and Regeneration of Marginal Lands

> *It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures.*
>
> Directive Principles of State Policy, Article 51-A

The prospects for organic farming are at the same time promising and challenging. Promising because there is a resurgence, an awakening to a newer dimension of the spirit of tradition manifesting itself in an increasing number of people from all sections of society and that all over the world. But we have to start our field work with less land less water in short an impoverished environment, with less seeds, less farm animals, less farmers even, representing an invaluable loss of empirical proven knowledge and faculty, an immeasurable loss of a caring and loving attitude towards the land, the animals, farming in general and nature.

Agriculture, if that word can still be used, has now little to do with the growing of food, with the reaping of nature's bounty. It is becoming exclusively a business for the growing of short term profits only. This exploitative mentality is growing very fast. Pollution, contamination and devastation are also bumper outcrops of modern scientific farming.

These are some of the challenges that we propose to elucidate in the second part of this paper. As regards the land all efforts at reclaiming the barren wasted lands by the local communities deserves priority attention.

One easy method of the practical sides of reclamation is outlined here in the first section. Of equal importance is the maintenance and enhancement of soil fertility of the vast stretches of marginal lands. Mere soil conservation is not sufficient. Soil development has to follow this initial effort. Green manures, composting and crop rotations and farmers seeds are the corner stones in this agricultural renewal. Various practical hints in this regard have been included in the following sections. Fertile areas where the land is suffering from soil fatigue or dying under the impact of life-endangering chemical substances need to be safeguarded and reinvigourated for posterity. Our efforts there must be directed to eliminate the destructive practices and replace them by ecologically sound methods, for instance, by using biological pest control. Last but not least all problems related to farming arise out of lack of understanding and thus from lack of harmony with the natural processes of the nourishing earth. Agricul-

ture depends on the farmers first and foremost and on their relationship with these natural processes. At this crossroads in time where a too mighty technology may threaten our survival on this planet we must rely not on more potent chemicals or the latest technological fancies but on the understanding of the farmers, on their care and love for nature, for plants, for the earth, for Mother Earth.

And in the meantime...start a vegetable garden!

Introduction

Of India's total land mass of 329 million hectares, about 266 mha. are, according to the sixth plan document, available for cultivation. However 150 mha. of this available area are threatened by wind and water erosion. These are the so-called marginal lands. Furthermore, according to the 1985 Report of the National Remote Sensing Agency, Hyderabad, 53,3 mha. of these marginal lands are to be considered "waste lands". Other sources quote 69 mha. as total "wasteland".

The reclamation of India's wastelands is thought of as being a Herculean task, if not nearly impossible. Usually one thinks of such desolate places as naturally and intrinsically inhospitable and hostile. The soil is either too dry or too wet, too stony or too steep. There are many places where regeneration attempts have been made, more often than not with very little success. Certainly it is a lot of labour, but when properly done, it can be of enormous benefit to the people and the economy of the country.

But many practical experiences have shown that there are actually few wastelands, but lots of "wasted" land. I fact the techniques for regeneration are very simple, and while financial inputs are necessary a lot can be done at a much lesser cost than imagined. Although we will concentrate mainly on the technical aspects of the subject, one has to first mention the social and economic issues.

The vast majority of the wastelands are community lands which are used for grazing cattle and where all sorts of produce is gathered. This includes firewood, leaves for fodder, and also herbs and roots. It is important to address all such real needs in any regeneration process. These issues must be discussed by the beneficiaries right from the beginning.

Practically speaking, the available common lands can be restored to productivity by dividing them into zones. One zone can be fenced off and protected while the other zones can be left open to grazing etc. Everyone would agree not to graze their cattle in the fenced area in order to let things grow. Grasses, herbs, etc. can be cut or harvested only after they have matured and the seeds have fallen to the

ground. There must be a prior agreement amongst the beneficiaries in this regard. A system of fines for trespassers or grazers can be imposed or a watchman can be appointed on a rotational basis. Once this area which was first fenced off starts to produce grass and fuel, a second zone can be fenced, protected, regenerated and so on, in succession.

All this of course, involves a considerable effort and commitment from the people concerned. They will have to cut the grasses themselves and stall feed their animals, instead of letting the cows graze freely. But it is worth the effort. It will be very rewarding and further benefits will come about unnoticed. These initial steps of care and protection alone can eventually change the appearance of community lands in a very positive way.

But only if local communities are effectively concerned about and involved in this process can there be lasting results.

What equally needs to be worked out is that the benefits accruing from regeneration will go to all parties concerned, eventually land owner and landless alike, and will thus not be a cause of discontent. There are however, some waste lands which are beyond the stage when natural regeneration is still possible within a short period of time. A comprehensive and systematic approach for the reclamation of such inhospitable wastes is then called for.

The actual method for reclaiming "wasted" lands comprises five essential steps:

- Fencing
- Soil and Water Conservation
- Introduction of Pioneer species
- Planting of Secondary species
- Enhancement of Soil life

Fencing

Obviously any area to be regenerated must be totally protected from grazing and free roaming animals. It must also be closed to human trespassers. "Do not step into the protected area unless it is absolutely necessary" should be the dictum. Hunters especially should be watched for. Partridges, hares and all kinds of small wildlife might start to look for shelter here. A protected area should be a small sanctuary, providing a safe nesting and breeding ground. These small animals will also bring in seeds of plants which we might neglect but which could be of considerable use.

Fencing is essential for the protection of a chosen area. It is important to spend some time and resources on a good fence. This will

always pay back in the long run. Stone wall fencing is common in parts of Rajasthan where stones are found in plenty. In other places fences are made from spiny shrubs or woven thorny bamboo panels. In many cases live fences are planted. *Euphorbia* and *Agave* species are very well suited for this job. A good live fence however consists of plants with horizontal branches as well as thorny creepers. The branches and vines will intermingle and an impenetrable thicket will form. If we look out attentively in our own area we are sure to find suitable, hardy, thorny species.

However good a stone wall or live fence might be it will not, as mentioned earlier, serve the purpose unless it is complemented by "social fencing".

Here are some examples of plant which have been used for live fences:

Trees	**Shrubs**	**Creepers**
Acacia chundra	*Gmelina asiatica*	*Ziziphus oenoplia*
Acacia horrida	*Carissa spinarum*	*Toddalia asiatica*
Acacia mellifera	*Phoenix humilis*	*Caesalpinia bonduc*
Pamburus missionis	*Securinega leucopyrus*	*Capparis zeylanica*
Parkinsonia aculeata	*Haematoxylon campechianum*	*Pterolobium hexapetalum*

Soil and Water Conservation

When the area is well protected one can start with the second job of soil & water conservation.

This consists of creating bunds with earth or stones to hold the rain water in place, where it falls, preventing any further soil erosion, or to slow down the flow of water down hill.

It is clear that such work starts always on the highest point of a given area or watershed, and not at the bottom or anywhere in the middle of the slope.

These bunds can be of different sizes and shapes. They can follow different patterns, such as contour bunding, crescent or half-moon bunding, netting, etc. Instead of bunds, pits and trenches can be made. The advantage of pitting for soil and water conservation is that the pits will collect organic materials like leaves brought by the wind and that they will gradually fill up with silt. When this happens one can successfully plant trees in them. In some places such as heavy clay soils where water logging could be a serious problem or on steep slopes vegetative barriers can be planted. These vegetative barriers are planted usually along the contour lines, mainly with

Vertiver grass. In heavy soils these barriers allow some water to flow but arrests soil movement.

A second step in the soil and water conservation measures is the creation of small water harvesters. Here one can take advantage of the places where erosion has already carved out the landscape. By building earth or stone dams across a gully for instance, one immediately obtains a small water reservoir. Where earth dams are made, care should be taken that an adequate overflow is provided for each such water harvester. The overflow must be made in such a way that the water can flow gradually over a long and large spread towards the next water harvester. If worked out correctly, a whole network of small water harvesting structures can be laid out. From these ponds water percolates into the soil and the effects of this will soon be visible. It would be better to keep all works small so as to make it easy to maintain. In other words, two smaller ponds are better than a bigger one, unless of course one is very sure about one's skills. Once water is secured the rest becomes much easier because *water is the driving force of all Nature.*

Pioneers

The third major step in the reclamation process is the introduction of pioneer plants. These are mainly small trees and shrubs, but they also include weeds and grasses. Nature has provided for an amazing variety of plants, even those that can grow on the poorest of soils and in the most hostile environments. Such plants must be identified and can be grown to form a pioneer vegetation—an initial cover.

It should be possible to just sow seeds of these pioneer plants around bunds, in trenches, behind stone crescents, etc. Sometimes a small furrow might have to be created to drop in the seeds. Where conditions are very bad, it might be necessary to dig or even blast pits and fill them up with good soil. In such cases pioneer plants would have to be raised in the nursery and planted out carefully. As they are early and prolific seeders pioneer plants should come up over the whole area within a very short time.

Whatever is the initial condition of the wasteland it should be possible to find a few species that will *somehow* thrive there. It is only up to us to identify suitable pioneer plants for our area. It is often remarked that only exotic trees and plants can be used as pioneers or that only indigenous vegetation should be used, but that is not the point. What is necessary is to evaluate their characteristics, function and above all, their performance. *A pioneer plant is used as a tool to tide over a difficult time. When the tool is no longer needed it has to be set aside.*

While looking for pioneers take the following criteria into consideration:

- easy to grow from seed or easy to plant without need for pitting or any other care
- ability to grow fast in very poor soils under adverse conditions
- drought or flood resistant
- resilient, capable of recovery after stress
- ability to produce large amount of biomass in a short time
- must have a powerful deep penetrating root system
- nitrogen fixing
- profuse seeding
- ability to unlock or accumulate nutrients from the vast reserves of the sub soil
- unpalatable to livestock

An ideal pioneer should have at least five of these characteristics. Furthermore, pioneers should be good colonizers. Their seeds should sprout in the full sun, they should preferably be intolerant to shade and have a short life span. It is not necessary that pioneers have a major economic value.

The function of the pioneers is to protect, cover and shade the soil as fast as possible. They will improve the soil by bringing about porosity and by adding organic matter. Some will fix nitrogen in the soil. Also, they will create a favorable environment needed for the secondary species to grow and thrive.

Note that what functions as a pioneer plant in one eco-climatic zone might not necessarily function in another zone. It is much better to search in the local surroundings or on similar problem soils in your area. Usually when a given area is well fenced off, the first plants to appear could be considered pioneers for that area.

Furthermore in selecting pioneer vegetation, the immediate needs of the beneficiaries, for instance their value as fuel, fodder or other uses must be considered. The point is that if an alternative source of firewood, etc., is provided, it becomes much easier to protect whatever valuable trees still survive.

How do we improve the fodder and fuel situation at this stage? In dry lateritic soils for instance, *Acacia holosericea* (now *colei*) or *Acacia tumida* and in saline clays *Acacia ampliceps* are excellent pioneer trees which will readily colonize whole areas. These fast growing pioneer trees can be grown to provide firewood within a time span of 2 to 3 years. These Acacia species (exotic) also produce edible seeds of high nutritive value. At a spacing of 3 x 3 m., they can produce ½ to 1 kg. of seeds per tree from the 3rd year onwards. These seeds can be processed and eaten in a number of ways. The easiest is to mill

them, mix the flour with ragi or wheat flour, etc. and then cook them in whatever way is preferred. If one does not feel ready to eat these seeds one can still feed the seed meal to milch cattle. A first grade animal feed at our doorstep!

For forage, some grasses such as *Cenchrus* species or legumes like *Stylosanthes* species are very good soil binders and improvers. They can grow on the worst of soils and can yield abundant, quality fodder.

When these crucial issues of fuel and fodder are properly dealt with, those difficult problems with grazing and chopping will surely subside.

Watch out! Pioneer plants are very invasive and care should be taken that they don't become a nuisance in agriculture fields. It is better to be very cautious when introducing pioneer species. It might be necessary to cut back the flowers to prevent seeding or even to uproot whole plants at a later stage.

Here are some more examples of good pioneer plants:

Shrubs	**Trees**	**Legumes and grasses**
Dodonaea viscosa	*Cassia siamea*	*Desmodium species*
Cassia auriculata	*Albizia amara*	*Cassia species*
Dichrostachys cinerea	*Dolichandrone crispa*	*Cynodon dactylon*

When the pioneers have grown, providing wind protection and improved soil conditions, one can start introducing secondary species. At first one can undertake trials with a wide variety of trees and plant species. This is to identify those species which could be successfully introduced later on.

Secondary Species

A fourth step in the regeneration process is the planting of secondary species. These will be for minor fruits, fodder, non-edible oil seeds, construction materials, timber, etc. The valuable and multipurpose indigenous trees can offer us all these multiple benefits. The initial trials will have shown which ones to select. But as the environment improves in time, more and more diverse, indigenous trees can be introduced.

It is very important to opt for a mixed plantation in the tropics. No single species should cover more than 10 percent of the given area. Diversity is the golden rule of Nature. Usually only trees are planted, but shrubs, creepers and herbs also have their importance and should equally be integrated in the environmental regeneration

process. Certain medicinal plants will grow as creepers or undergrowth in the forest. Most others however prefer to grow in open spaces in the full sunlight or in partial shade. Hence it becomes necessary to retain some open areas especially for these medicinal herbs. Other fodder grasses and legumes can also be introduced here. The cowherds are special good sources of information concerning the most valuable fodder grasses. Guinea or Hamil grass (*Panicum maximum*) and *Sesbania* species and *Desmanthus virgatus* are also excellent plants for this purpose.

After planting the secondary species, the pioneers can be pruned and the foliage used for mulching. *It is not wise to clear cut the area before planting.* This would undo all the work that the pioneers have done. Put about two inches of mulch in a circle of one meter dia around the seedlings. It is better that the mulch does not touch the stem of the young saplings, leave a gap there of one inch mulch free. Mulching will protect the soil, conserve moisture and enhance soil microbial activity. Earthworms and termites will proliferate and a soil building process will start.

The whole question now is which species do we use as secondary species? This will of course vary from area to area. One would need to find out about the original vegetation of the place. We can get a clue from the sacred grooves, old temples, remnants of indigenous forest nearby or consult the elders in the villages. When choosing suitable species a lot of emphasis need to be given to the minor fruits. When mangoes or other important fruit trees are grown in farmers fields, the fruits are likely to be sold for cash income, leaving very little for the village children to enjoy themselves. Having a grove where children can roam climbing trees in search of berries and adventure, will not only contribute to the healing of the earth but also to the healing of men.

See if some of these minor fruit species are suitable to be grown in your area.

Emblica officinalis
Syzygium cumini
Ziziphus jujuba
Manilkara hexandra
Diospyrus melanoxylon
Carissa carandas
Rhus mysorensis
Coccoloba platyclada
Grewia asiatica
Mimusops elingi
Alangium salviifolium
Pethecellobium dulce
Cordia dichotoma
Feronia limonia
Aegle marmelos
Phoenix sylvestris
Borassus flabellifer
Mutingia calabura
Terminalia catappa
Phullanthus acidus
Pamburus missionis
Capparis zeylanica

A similar list can be drafted of other valuable species that are essential for life in the village, for instance for non edible oilseeds, housing and roofing materials, for basket weaving, fodder and so on.

Soil Life

A soil has its own life cycle. One can say that a soil is born, matures and eventually dies. The dying of the soil is called erosion and this is what creates all this wastage and devastation.

How can we improve soil life in these barren lands? There are two groups of soil creatures which we can harness in the reclamation work. These are the *macro* and *micro organisms.*

Go to the nearest tree on the roadside, brush some leaves aside and you will immediately see small black creatures running away, looking for shelter in the darkness under the litter. These are part of the *macro fauna*. These creatures constantly move under the leaves, chewing them, burrowing in the soil and depositing their excrement.

Macro-Organisms—Earthworms and Termites

Two macro-fauna species are of immediate concern to us here—the *earthworm* and the *termite*. The earthworm can be active only during the relatively short rainy season. But the white ant is active for most of the year! Its beneficial action for the regeneration of barren lands is unfortunately not understood and thus not appreciated.

Let us first take a closer look at the earthworm.

The earthworm has three major functions. One, it opens the soil by making burrows, thereby facilitating the infiltration of air and water. These burrows will readily be colonized by the hungry and thirsty roots of plants. Two, it neutralizes the soil pH. In acid soils, calcium is in short supply. The earthworm has special glands which secrete calcium. When the soil pH comes close to neutral, it becomes easier for plants to extract nutrients from the soil. Earthworms eat and digest the soil, mix it with organic matter and throw it out in

Earthworm castings contain:

- *Two times the available magnesium*
- *Five times the available nitrogen*
- *Seven times the available phosphorus*
- *Eleven times the available potassium*
- *Thousand times more micro-organisms than the surrounding soil!*

the form of castings. These little heaps of earth are the only fertilizers we need.

Now, the termite; as mentioned, the termite is active almost all through the year. It takes organic debris down into the soil and brings up or covers its "food" with soil. This soil has been mixed with their saliva and is very much richer than ordinary soil. Then, their excrement and dead bodies all contribute to the enrichment of the soil. The numerous tunnels they make, act as ducts for the water to percolate into the soil and for air to circulate. In tropical rain forests, the soil seems to consist of termite excrement only and is so porous (80% air) that it can absorb the heaviest of rainfalls imaginable! Roots of plants can also follow termite tunnels.

It is generally believed that termites will eat or kill the seedlings. This might be so if there is nothing else for them to eat. But if this were true there would not be any surviving forests and the highest density and diversity of termites are actually found in savannas and in the forests! Usually termites "eat" dead wood, dry organic matter and some grass. With this material they cultivate their gardens. In their gardens they grow mushrooms which is their source for their food and water.

The whole question now is, how to attract earthworms and termites? Mulch put around the seedlings will be a sought after place for whatever earthworms and termites still exist in the area. If termites are few, introduce them by catching a few queens when they swarm out after a good summer rain. To catch the other working termites put some straw or wood shavings in a plastic net, sprinkle some water on it and leave it in the evening near the place where you saw termites recently. The next morning you should have a bountiful harvest of workers. Take the captured termites to the reclamation site and release them under the mulch layer. Keep this spot moist until the next rain.

To attract earthworms it might be sufficient to put a handful of cowdung under the mulch. If not culture the local earthworms separately and introduce them during the rainy season.

Micro-Organisms

Then there is a very vast domain of tiny little creatures, the *micro-organisms*, without whose help, we would not even survive on this planet.

One gram of soil can contain 1 billion or more organisms! Of course, there is a strong link between the macro-fauna and flora, and the microbes. The greater the presence of macro-fauna, the better will it be for the micro-organisms. Also, they form an intricate commu-

nity, each one helping or depending and subsisting on the other. It is a chain and we should not break any links in it.

How can we use micro organisms in the regeneration process? We can culture them separately and then inoculate our soils with them. Bio-fertilizers or bacterial cultures are now available almost everywhere in India. Unfortunately only a few organisms are being mass multiplied. Very often the available cultures are not up to the standard also.

Some of the most useful cultures are *Azotobacter, Azospirillum* and *phosphobacteria.* The first two are nitrogen fixers while phosphobacteria help in solubilizing available phosphorus.

Along with *phosphobacteria*, it is good to use rock phosphate. About 40 to 80 kg. per acre is enough. For leguminous trees appropriate rhizobium cultures can be used, and for trees like casuarina use the *Frankia* strain. The growth performance of secondary species has found to be greatly enhanced by the use of these biofertilisers. Plant height increased by 23% and girth increased by 50% in field trials (Hameed and Annamalai).

Actually, the best thing is to have a wild grove here and there, a place undisturbed by man. When we collect soil from such a place, we are sure to get an interlinked chain of micro-organisms which will function far more efficiently than isolated cultures.

Plants, especially trees absorb water and nutrients with the help of small micro-organisms which are called *mycorrhiza.* These are root fungi. They live in symbiotic relation with roots of plants. One of the common mycorrhiza is the *puff ball* or *Pisolithus tinctorius.* The puff ball which we see is actually the fruiting body of the fungus and it contains spores. These spores, when mixed and stirred in water, can be used on sprouting seeds or for irrigating young saplings. This is especially useful when very denuded and degraded areas are being afforested. Be careful not to inhale the spores of the fungus as it will cause severe irritation.

Another type of mycorrhiza is known as VAM (vesicular arbuscular mycorrhiza). It is very difficult to multiply these mycorrhiza as they are host specific. One simple method to collect VAM is to look for a good healthy tree in some forest grove, dig up some of its small roots, and collect the soil around the tiny hair roots. This soil, with some of these tiny roots can be used as an inoculant. For teak trees, use the 'teak' inoculant. For *Pongamia*, use the "Pongamia" inoculant and so on. When there are larger numbers of trees to be planted, one can select "mother trees". Build up a small pile of organic litter under its canopy and keep it moist. With time the tiny white feeding roots will invade this "compost pile". In this way it becomes very easy to obtain the inoculant either for the nurs-

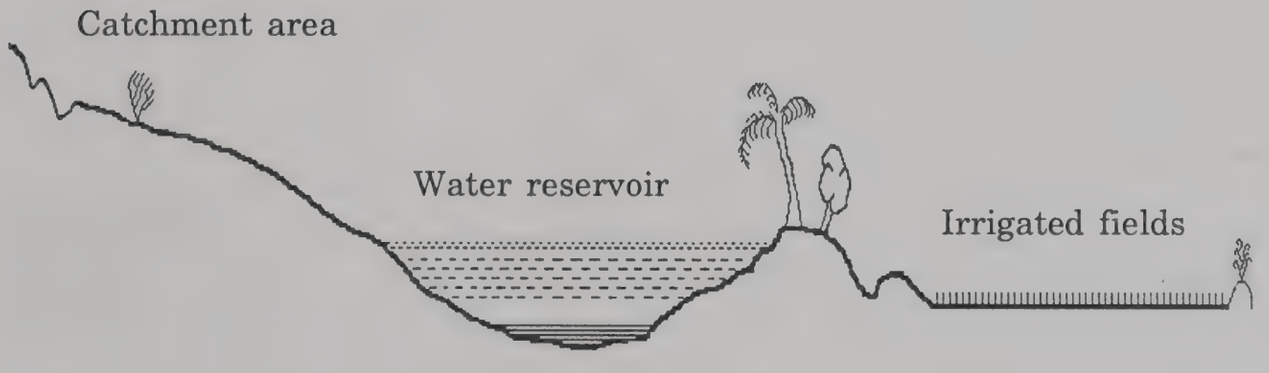
ery or while transplanting. We should be aware that all these organisms live in the dark of the soil, so never expose the inoculant to the sun and use it immediately. It is best to use the inoculant with saplings as mycorrhiza develop only in the presence of roots.

What are the benefits from all our efforts at waste land reclamation? Besides a number of benefits already mentioned before like minor fruits, fodder and non edible oilseeds etc. as an outcome of the environmental improvement wildlife will develop in great numbers (hares and partridges) providing a valuable source of protein. Also bee keeping or the collection and processing of medicinal herbs can further be valuable and remunerative activities. They are immediately tangible or visible benefits. But other advantages like an improved water table might take more time before being noticed.

Common lands and Agricultural lands

Look at the sketch below. It will help us understand the close relationship between the proper management of common lands and agriculture.

Before reclamation

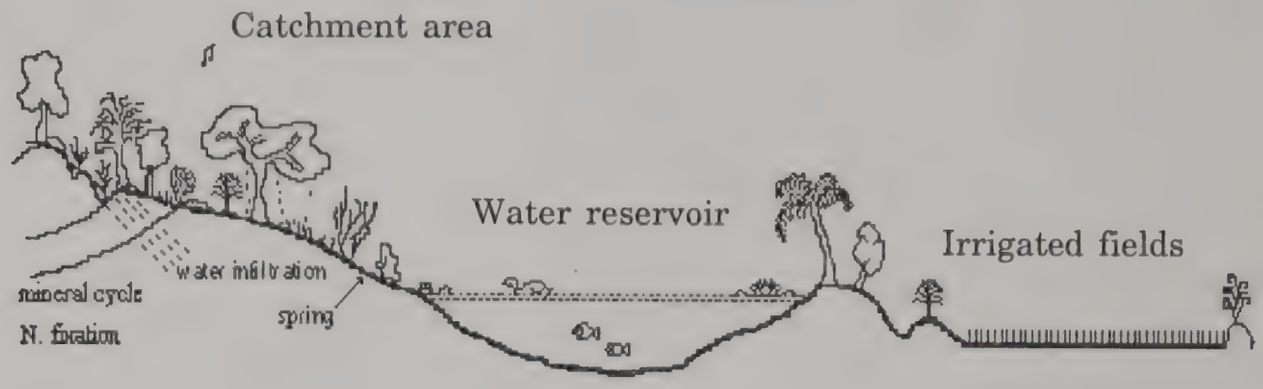


We can see how everything is inter-linked.

Erosion destroys drylands, creates floods and droughts, leads to the silting up of water bodies and reduces the irrigated areas. Springs and rivers dry up and arid tendencies set in.

Dwarf varieties produce less fodder, hence higher stress on grazing lands, which in turn enhances erosion, siltation, reduction in irrigated areas, leading to less fodder availability and thus less manure and higher dependence on external sources.

After regeneration



Each bund made, each tree planted, each little positive action from our side has its repercussions on the whole system. Dust storms and scorching winds will be arrested, the whole micro-climate will change for the better. A bund holds back soil and water. Water infiltrates the soil, and vegetation profits by this. So does the water table. Springs will rise and water will flow to the tanks for a longer period. Trees will help the water to infiltrate and to rise up. They will bring up minerals from the sub-soil and deposit them through their leaves on the soil surface. They will produce fodder and their twigs and trash can be used to start the cooking fire. This will save dung from being burnt, because the dung is needed for the agricultural fields.

Conclusion

Care and protection of the wastelands by the local communities can of itself regenerate the land if it is not too degraded. In other places simple methods as the one described above can be followed. It is really not such an impossible task to reclaim even the most degraded watersheds.

Plant trees and shrubs that the soil *wants* to grow. This might not be necessarily the ones that *we think* should grow. What we want can be planted later amidst the lush greenery of the regenerated "wasted" land.

Part IV: Organic Practices—Experiences and Guidelines

Humanity will reach the organic (biological) age, or it will cease to exist.

— H.P. Rusch.

Introduction

In many people's understanding organic farming is limited to a notion of an agriculture without chemical inputs. But organic farming encompasses more than that. In short, one could say that organic farming works along the principles found in nature. It works in harmony with nature rather than against nature.

Thus to understand organic farming one has first to understand and know the natural system. The tropical rain forests are standing examples of a sustainable natural system. These rain forests have been keeping up their enormous diversity and wealth of production for the last 60 million years! Moreover this abundance of life has flourished and sustained on the poorest of soils. If there is anything sustainable on this earth it must be these endangered rain forests.

The one thing for us to do is to study with a quiet and open mind such a natural ecosystem. Such systems, if and where they still exist, are the only teachers we have and really need. Some of the lessons we can learn from the forests are: biodiversity, biocoenosis, indigenous species, succession of species, recycling, multi-tier cultivation, mulching, etc. There is no end to the wealth of knowledge we can freely imbibe from the forest. The learning process is limited only by our present constraints in understanding its nature and functioning. In the same way organic farming grows and develops, site specific; it is an unending education. Practically speaking, such components as locally adapted seeds, crop rotation, composting, intercropping, optimum recycling, etc. will thus form the basis of an integrated organic farming system. Let us now look closer at some of these components.

Multi-Tier and Alley Cropping

In almost all natural systems even in the Kalahari desert, we find this multi-tier cropping pattern. In orchards and plantation crops, this approach is well established. Arecanut is grown with cocoa, pepper, turmeric or vanilla. Coconuts are grown in combination with bananas and pineapple. In orchards, lemons grow beside casua-

rina trees and in the lower storey we find *tulasi* (*Ocimum sanctum*) and vegetables. Hedges of *Gliricidia* or leguminous plants are grown between mango trees and beneath in the shade of the canopy we find *Pseudathria viscida,* a living mulch.

Let us examine the nature of the leaves. Cashew leaves are very ligneous and hard to decompose. The cashew tree, a sun loving plant will thus fit well with trees which do not give any significant shade like *Sesbania grandiflora* in the upper storey, *gliricidia* as a hedge and companion and a legume like *Stylosanthes hamata* as a soil cover. All these plants have "soft" leaves. This mixture of soft and hard leaves will lead to an excellent humus formation.

In the drylands this multi-tier system gives rise to what is called *alley cropping*. Every two or three meters, or according to the inclination of the farmer or the need of the land, a hedge row of perennial *Pigeon pea (red gram), Gliricidia, Sesbania egyptica, Mundelia suberosa, Tephrosia candida*, or any such shrub that you might find in your area is planted. These will form the alleys. Until these plants are well established, they are allowed to grow undisturbed in the cropped fields.

The alley plants are actually nutrient pumps, bringing up elements from the deeper layers of the soil and depositing them through leaf fall on the surface. Nutrients lost due to leaching are equally absorbed and brought back in circulation. Alleys will also provide protection to the soil and plants.

Between these hedge rows, crops are sown. Then, the hedges are cut back and the twigs and leaves are used to cover the freshly sown fields. This covering mulch layer will conserve moisture and when the cut twigs and leaves decompose or are eaten by earthworms, they become extra nutrients for the field crops. During the cropping season, the hedges re-sprout and may have to be cut back once more or even twice. Each time the foliage can be recycled as mulch for the standing crop. One does not need to put these clippings neatly on the soil. One can just throw them carelessly between the plants. The cut leaves will soon shrivel in the hot sun and the wind will finish the task of depositing them on the soil surface.

It might be necessary not to prune the hedge plant completely, but to keep one twig or branch, to keep the hedge plant alive and to hasten its recovery. When the crops are mature and are harvested, then the hedges are allowed to grow undisturbed during the entire dry season. Like this, as the summer advances and it becomes hotter and hotter, the fields become greener and greener!

Moreover, creepers can also be grown in the alleys. Their growth is also checked during the cropping season, just like the hedges, but in the dry season, these creepers are allowed to spread out covering

the area between the hedges. Some *Canavalia* species do this job very well. Many other plant species could be used. The principle is that *the soil should be covered for a maximum period of the year,* but mainly so during the hot and scorching summer months. In a way, this is using the lean dry season to grow a crop of green manure!

And lastly, trees having deep tap roots and few surface roots can also be planted in the alleys. *Hardwickia binata* and *Pterocarpus santalinus* are such trees that do not form a spreading canopy and the side branches can be lopped for fodder. Their wood is very valuable timber! Other trees that might be planted in the fields at appropriate distances are *Acacia nilotica var cupressiformis, Acacia ferruginea, Terminalia tomentosa* and *Prosopis cineraria.* The latter forms part of the traditional agro-forestry system as can still be seen in Rajasthan. There is no need to mention that a fruit tree, such as Mango or Jackfruit, planted in a corner of a field will keep the farmer going through years when his crops might not be so good.

A tree in a field can be seen as a savings account. One sets aside a little bit of crop space for the tree, and in due time collect your benefits hundredfold.

But this is not all that the alley system can offer us. It has more possibilities as well. Consider having a trench in the alley. This trench can direct excess rain water towards water harvesting ponds. Even in "drought" years, very heavy rains can occur. Rains of more than 20 cm. a day are very common in the tropics, while there might be as much as 3 weeks or more between successive rains. This rain water harvesting system might not work so well in very sandy soils, but in loamy or clayey soils, this can surely be a real boon to dryland farming. Water harvesting ponds will need to be lined with silt or clay, except in a heavy clayey soil itself.

During periods of stress or during critical stages of plant growth, such as emergence of the seed, tillering, panicle initiation or around flowering time, water can be recycled in the dryland alley cropped field through the same trenches. This, of course, needs a pumping device, some pipes or cleverly designed water distribution channels. It is not the intention to irrigate the fields, but to keep the soil moist, prevent it from drying out, to keep the water element on the land or to provide a protective or life saving irrigation for the standing crop. One irrigation at the needed time can double the harvest or make the difference between success or failure.

Mixed Cropping

Closely linked to what we learnt above, is the practice of mixed cropping. For this we can take profit from the proven benefits of tra-

ditional farming systems. One crop combination still in use today is that of growing millets, pulses and oil seeds as a mixed crop. In some traditions up to nine different crops are grown together in one single field (*Navdanya*) and in the Javadi hills of Tamil Nadu tribal farmers grow up to 42 species a year!

One thing that can help us is the fact that when plants mature certain nutrients are returned to the soil (e.g. potassium). We should therefore aim at a combination which allows for one plant to come into flower (when the metabolism is high) when the other crop is mature or has been harvested. For example in a combination of barnyard millet (4 months) and kodo millet (6 months) the first millet will be harvested at a time before the other one starts flowering. Only the earhead will be cut from the barnyard millet. The rest of the plant, stalks and leaves are left in the field. Gradually the stalks disappear in the greenery of the kodo millet.

It is also known that plants have their own feelings, likes and dislikes. It is known that maize gets along well with beans and cucumber. Tomatoes go well with onions and marigolds. On the other hand do not plant beans and onions together as they do not get along at all. The insects that attack carrots will be chased away by the insects attracted towards leeks and vice versa, so plant these two together. In this way, mixed cropping is a cheap assurance against pest infestation.

Some useful crop combinations from South India are given below.

- Pearl millet, peanuts, redgram, castor
- Pearl millet, moth bean, wild cucumber (medicinal)
- Ragi, black gram, red gram, sesame, cowpea
- Peanuts, sesame, cowpea
- Niger, sesame, green gram, red gram, cotton and castor
- Barnyard millet, kodo millet, lablab beans, red gram
- Early ragi and dryland rice
- Sorghum, cowpea, red gram (pigeon pea)

Often very misunderstood in farming is the usefulness of weeds. Here one makes a distinction between grasses (*Gramineae*) and weeds. The grasses must be pulled up from the fields to feed the cows, or they can be recycled as a mulch layer or directed to the compost pile. Other non *Gramineae* weeds can be very useful not only because of their medicinal value, but because of their deep burrowing taproot. The weaker root system of the cultivated plants can profit by the backbreaking labour of these subsoiling weeds, by just following their roots deep down in the soil where there is moisture. One or two of such weeds per m^2 are highly beneficial for the cultivated crops. We should study the root system of our weeds!

Another example of traditional mixed cropping pattern is currently being followed by a farmer from Dharwad District in Karnataka, Shri D.D. Bharamagoudra.

Bharamagoudra grows Kharif (summer) and Rabi (winter) crops. In the Kharif season, he grows sorghum, groundnut (6 months), peanuts (3 months), cowpea, green gram, pigeon pea, chillies. Also a mix of vegetables such as cluster beans, ladies finger, beetroot, onion, garlic, pumpkins, radish, carrots and gourds are grown in dryland conditions. His Rabi crops are sorghum, wheat, black gram, safflower, sesame and sunflower. A few crops overlap both seasons.

The main Kharif crops are sorghum and red gram, planted in lines interspersed with lines of green gram and cowpea. Rows of niger are sown on the southern and western borders of the field. Every row of sorghum is always mixed with *rosella* and *coriander* (to control striga weed and some insects).

Chillies are started in raised seedling beds 3 ft wide, in the month of May. Only 225 grams of seed are used for raising seedlings for three acres. The seeds are sown very thinly in rows and covered with cotton stalk. Watering is done in the evenings everyday for 8 days. After this initial 8 day period, the seedlings are watered every 2nd day. This produces tough and healthy seedlings, though small in size. After 40 days, they are 3-4 inches tall but have a hard stem and deep roots. The common practice of other farmers is to water heavily and this makes the seedlings weak and brings down the survival rate when transplanted. With stress treatment at the nursery stage, the chilly plants pick up very well once they are transplanted after the monsoon arrives. They are planted in rows 2.5 or 3 ft apart.

In the last week of September cotton is sown between the chilly plants and mixed with coriander, rosella, horsegram and sorghum.

The main Rabi crops are sorghum and wheat. These are sown (last week of September-first week of October) after a 30-40 day crop of green manure (started in July-August). The green manure is a mix of green gram, horse gram, fenugreek, coriander, cowpea, sown in furrows 15 ft apart. Green gram flowers on 31st-32nd day and all the others flower within 40 days. It is then ploughed and after 8 days harrowed. Some of these plants will nevertheless grow back and form an intercrop in the Rabi season.

Bharamagoudra's experience is that appropriate crop combinations are essential to maintain good fertility levels in the fields. Compost is given to the land only once in four years (on a rotational basis). His conviction is that pests can considerably (by 75%) be avoided by intercropping and crop rotation. The diversity of crops keeps away pests. In his area the pest problem is not as serious as in some other

area because most farmers maintain a certain crop diversity. It is the normal to grow at least 6 varieties in 3 acres.

Bharamagoudra has been able to cultivate crops better than those who use chemicals. He has, moreover, not used any crop protection measures and above all, he is able to grow almost everything his family needs.

Crop Rotation

If mixed cropping cannot be practised then surely a crop rotation scheme must be followed if we want to assure a sustained fertility status of our soils without spoiling them. There are 3 fundamental reasons why crop rotation should be followed:

- Not all plants have the same nutritive needs.
- Soil structure is improved through the action of roots.
- Pest buildup is avoided.

As an example of the first point let us take beetroot for instance. Beetroot is a high potassium demander but needs little nitrogen. Wheat on the other hand needs little potassium but more nitrogen. Hence wheat is an ideal crop to follow beetroot. Also mustard can be grown after beetroot, because it also needs little potassium and phosphorous but more of sulphur. Mustard is thus equally a good crop to follow rice because in the reduced zone of the water logged fields sulphur builds up. By following such types of rotation we give, as it were, more time to the micro-organisms to transform or mobilize the various elements in the soil. Now if one would grow only mustard after mustard, then the soil would soon be depleted not of sulphur but of assimilable sulphate, because mustard removes sulphates faster than the micro-organisms can "process".

Secondly, all plants do not have the same root mass or root action on the soil. Some plants like pigeon pea *(Cajanus cajan)* go very deep in the soil in search of moisture. Such types of deep-rooted plants besides leaving behind a lot of organic matter in the soil, will aerate the soil and create "tunnels" for the roots of the succeeding crop to follow. Both these factors will enhance microbe activity which again will lead to a better mobilisation of nutritive substances. Some crops will leave lots of roots in the soil but others like beetroot or other root crops will leave very few roots in the soils. This root action also explains why growing a mixed green manure crop with deep penetrating roots will be beneficial for the crops that follow.

The next advantage of rotation is the avoidance of pest buildup. For instance, in vegetable gardening, leafy vegetables will be followed by root plants such as radish or carrots, which in turn will be followed by fruit crops like brinjal or tomato and ultimately this will be

followed by grain vegetables like peas and beans. It is important to take the plant families into consideration. Thus radish should not be planted after cauliflower or carrots after celery because these plants belong to the same family. By following such a rotation, pests have little chance to proliferate.

Rotation can also be of help against the buildup of weeds. In sorghum *(sorghum vulgare)* the *striga* weed is a considerable nuisance. By rotating sorghum with coriander or horse gram, one can eliminate the danger of striga infestation. A special rotation, if that word can be used was earlier practiced in rice growing areas. By planting a purple pigmented rice, every fifth year the farmer could easily eliminate all grasses, foremost those of the *Echinochloa* family which mimic the rice plants so well.

Seeds, Selection and treatment

"A farmer without seeds is like a soldier without a gun." This saying is from a bygone age and seems to have no relevance any more, not because we have become more peace loving, but because the vital traditional link between farmers, nature, plants and soil has been lost.

Of all edible and "useful" plants growing on this wonderful earth, the overlarge majority (about 90%) have evolved through natural processes. Human beings since the beginnings of agriculture some 8000 years ago, have apparently been instrumental in the evolution of about 9% of the plants grown for food and other uses. It is estimated that only 0.1% have evolved from modern breeding methods. Yet that 0.1% bred by modern corporate seed manufacturers, in barely a wink of evolutionary time, have turned into a real threat to our genetic base.

There are many reasons to be worried. The "new seeds", let us call them like that, are occupying the lands and pushing the native seeds, the landraces out of existence. Yet the landraces are used to "improve" the new seeds. A paradoxical situation.

Also the new seeds have a very narrow genetic base. In a survey conducted in the U.S. in 1981, 95% of all wheat seeds on the market contained materials from the same few "elite" strains (for maize the percentage was 83% and for soya 49%!). This narrow genetic base leads to high risks in farming. Such seeds can remain in the fields only when backed up with massive applications of fertilizers and harmful pesticides. These chemical substances have created severe imbalances in the ecosystem and are affecting our very survival. Due to pesticide action in our bodies the human sperm count in the western world is now 50% lower then it was in 1939. To rely on engi-

neered seeds is equally dangerous as the example of Monsanto's transgenic "Bollgard" cotton has shown. Besides life is too complex, intricate and unpredictable and as children playing with fire, we are at a risky game. Genes have jumped over to other plants and could possibly produce "super weeds".

But the real danger is that the farmer looses touch with the natural realities. People have domesticated plants and animals, now we seem to have lost that capacity and we haven't domesticated new plants or animals since a long time! Farmers have created thousands and thousands of different varieties of rice, wheat, apples, etc. We in the last 30 years have eliminated 90% of them. But who among the farmers can still create new varieties?

We have actually fallen far back and we could be considered quite illiterate in comparison with farmers of earlier ages. Aware of the dangers of seeds, seed banks have been created. Conserving biodiversity is the fashion the world all over. But it is not only about genetic erosion that we have to ponder, but about mental erosion and maybe about the erosion of the inner and outer dimensions.

Seed banks "conserve" huge germplasms. However one of the world's largest seed conservation centres in Colorado (the seed storage laboratory of Fort Collins) is situated near an earthquake prone area between an atomic power plant and a nuclear weapon "facility"! When in 1989 seed germination tests were done, less than one third of the seeds germinated in this world's largest seed morgue. Conditions have, it seems "improved" in the last decade.

There is really only one way out. Seeds have to be conserved on the farmer's fields where, as cultivated species, they have evolved in the past and can easily evolve for the future. Indeed there is an undeniable link between the seed, what it will express and the environment in which it grows. The plants determine the environment as the environment determines the plants, just like the climate determines the soil and the soil determines the climate.

By improving soil fertility, strengthening the ecological components, attention and selecting from spontaneous mutants, farmers can still create better yielding seeds, without the loss of diverse other valuable characteristics such as mineral and protein content and thus palatability. Various farmer's technologies still in vogue such as the salt water selection method, cow urine treatment and many other such practices, help plants to evolve in their natural habitat.

For the salt water selection, make a saturated solution of sea salt and water, drop the seeds into the solution and skim off the light, floating seeds. Rinse and use the heavier ones for seeding. Seeds can be soaked in a 10% cow urine solution for 24 hours or in pure urine for a few minutes.

Always, in all continents farmers have been aware of the special influence of the moon. The experiments of Kolisko have shown that plants sown two days before the full moon have a better yield and are of a better quality. For wheat and other such cereals the increment was up to 25%, for maize 30 to 40%, and for peas and beans up to 80%!

A most interesting example of seed treatment is the traditional practice of caring for cotton seeds. Here are the words of D.D. Bharamagoudra (whose work we have already discussed earlier):

"Take small quantities of water and rub the seeds with the palm, the remaining cotton attached to the seed will be removed. Then rub cow or bullocks dung on to the seeds. Following this add a very small quantity of groundnut oil, some quantity of pounded garlic, turmeric powder, pounded dry ginger, a little curds or buttermilk, wood ash and lastly a little dry mud. After this the treated seeds are dried in the shade. Castor, coriander, sorghum, horsegram seeds are added to these cotton seeds and stored. The cotton will be sown end September up to the first week of October in the chilli crop, at a spacing of two feet between rows and one foot from plant to plant."

The Art of Composting

Organic farming is for many people associated with bad smelling piles of animal manure mixed with straw, some leaves and ashes from the kitchen fire. It is a heap of garbage infested with flies and pathogens, a symbol of poverty and misery. Indeed this is very true for the millions of tons of unprocessed city wastes that are carelessly dumped outside the city or wherever it is out of sight. Small farmers, unable to procure costly fertilizers eagerly flock to these dumps with their bullock carts and bring the foul smelling rubbish to their villages and fields.

But what is called compost is a very different thing and has to be distinguished even from the farmyard manure that is used by most of the farmers in the villages. Basically composting is a fermentation process, just like making curd, cheese or wine. We tend to be more attracted towards the last type of fermentation than towards the first one! But the health of the soil, plants and animals including our bodies, depends not on wine but on this fermentation process which is called composting. There are many known, sometimes very different ways of making compost. Here some basic guidelines and explanations are given.

Why is composting necessary?

The soils in our fields consist of different layers called horizons. When we dig a hole somewhere in a woodlot or in the fields, we can

clearly distinguish 3 such horizons. The surface layer is the organic horizon called the A horizon. Here we find the litter which is gradually being processed by numerous soil creatures. Below this we find a layer of brown earth where the decomposed organic matter from the A horizon mingles with the mineral matter from the soil. In a third horizon, called C, we see only clear mineral soil. In the forest the organic A horizon being build up over the seasons, is very pronounced. The leaves and twigs fall to the ground where buck and deer graze and add their manure to the litter. Above the crown of the trees birds sing and they garnish the organic litter layer with a spread of rich droppings. This organic carpet is slowly transformed into a balanced nutritive substance for trees and plants and the cycle starts again.

Our cultivated fields are however not forests and farmers, when they work the soil, destroy the organic A horizon with their plow. So in fact, the farmers have to manage the natural processes occurring in this horizon outside their fields in a separate place: the compost pile.

Composting is further needed to stimulate the organic processes in the soil. So by recycling all farm residues and other organic debris in a compost pile, farmers can maintain a sustainable productivity of their agricultural fields.

Where shall we make the compost?

Before studying how to proceed with composting we need to find a good spot for putting up the compost pile. Inspired by the humification process of the forest, we will select a place well protected from the direct impact of the sun, rain and wind. If no such place is available we need to create one. We can plant hedges 3 metres apart with fast growing plants like Gliricidia, Sesbania or Erythrina species. When the hedges grow, we can regularly chop some of the branches for cattle feed or for leaf manure or return them back to the compost pile.

Be aware that for composting you will need water. So water should be easily accessible. One can use water from the pond or even waste water. The composting area should also be accessible for the bullock cart.

How big should the compost pile be?

First it can be as long as one wishes, but since air is needed for the bacteria and humifying fungi, keep the width to maximum three metres (3m) and the height to one and half metres (1.5m). A width of 1.5 m. is recommended for villages.

It is not only the size that counts but also the shape. This depends on the climate. In high rainfall areas, the compost pile should

be constructed like this /\. We can get some inspiration from the inclination of the traditional roofs of village houses.

What can we put in the compost pile?

Essentially, all organic matter can be composted. Residues from the fields and stable, straw, leaves, weeds, all kinds of trash like sugarcane leaves, saw dust, organic residues from local industries like coir pith or pressmud and ashes, kitchen wastes etc.

When we use cotton stalks, pigeon pea stalks, cassava stalks and twigs, it is necessary to chop them into small pieces with a hand chaff cutter or if that cannot be done, spread them on the road. After a few bullock carts or lorries have passed over the material, it will be well crushed and suitable for composting. But soil is also necessary. Good soil must be added to the compost pile and if possible, some cow urine. Cow urine is a valuable asset that is needlessly wasted in many farms. By using a bedding of straw, coir pith or any absorbent dry matter, the urine can be saved for the compost pile and so for the fields. Another method is to scrape the soil where the animals stand and sleep, which is always drenched with urine. Mix this with ashes and spread it on the pile. Put fresh soil under the animals regularly. It will avoid the proliferation of flies and other pathogens and it will keep your animals happy as well.

Heaven-sent plants such as water hyacinth (Eichhornia crassipes) and other aquatic weeds or Parthenium and Eupatorium are abundantly available in many places. Their value as a source of compost is sadly overlooked. Parthenium seems to cause irritation to some people so the plants must be cut before they flower. Water hyacinth absorbs toxic chemicals released in the environment by unmindful industries. So be a little careful here and gather strength to fight industrial pollution. Where pressmud and coir pith are available by mixing these two ingredients alone in equal proportions by volume one can provide a considerable amount of compost at little expense.

What else is needed ? Water and Air. These are very important "parts" of the pile and need special attention. We will deal with them separately.

The Nature of the Starting Materials

We need to know something more about the starting materials if we want to succeed in composting. The production of humus will depend on whether the starting materials are rich in cellulose and lignin. Leaves, straw, coir pith, sugarcane trash, sawdust are very good sources of cellulose and lignin. However they are poorer in other substances which are essential for the fermentation process, like nitrogen

and phosphorus. Animal dung, biogas slurry, oil cakes, green plants, these are all rich in nitrogen but poor in lignin. That explains why we need to mix all these materials properly. Ideally the Carbon : Nitrogen ratio should be between 20 : 1 and 30 : 1. Practically speaking this rule has not much value as farmers can only use what they have available.

How to build up the compost pile?

Here the serious work starts. Mostly in the villages the farmer throws his "wastes" in a haphazard manner in a heap of a 'difficult to describe' shape. In a certain sense piling up organic matter that way is basically wasting it. For instance, if badly done, from about 30 tons of starting materials only 3 tons of humus will be produced, while if we follow the proper rules of composting, 10 tons of humus can be obtained.

The compost pile must be constructed on good soil. Contact with a natural fertile soil and hence with a whole intricate community of micro-organisms is necessary.

1. First put a layer of absorbent dry matter about 6 inches thick. Sprinkle this with some water.

2. Spread cow dung evenly over this first layer. If little cowdung is available use green weeds or kitchen waste. Various grasses and weeds containing seeds must be put in the centre of the pile. There the heat will destroy rhizomes and seeds. This also holds for plants that easily take root, like Ipomea. The cowdung can be mixed in water and sprinkled over the constituent layers.

3. A thin film of half an inch of good soil and some ashes must be spread evenly over the animal dung. If the soil is acidic or contains a lot of cow urine, ashes and a source of calcium must be mixed with it. Calcium can be obtained by crushing eggshells or sea shells, or by adding lime stone powder, dolomite or a whitish yellow looking subsoil that one could find where open wells are dug or in deep trenches.

These three layers of dry organic matter, dung or green plants and soil form one unit. Now in the same way, add another unit and so on. The pile can be built up until a height of 1 to 1.5 metres. Then the compost pile needs to be dressed.

4. A thin layer of soil of one to two inch thickness followed by sugarcane trash or old banana leaves form a good covering. The cover should not be too thick because the compost pile should be able to breathe.

What happens in the compost pile?

The pile heats up and can even reach 600 to 800 C. This a good

indication that the pile is well aerated. (In anaerobic or cold composting systems the temperature will not exceed 25^0 C.) A high temperature is needed to pasteurize the compost pile, to kill off the pathogens. The eggs of parasitic worms will be destroyed only when the temperature goes up to 65^0 C. This rise in temperature is due to microbes called thermophilic bacteria and actinomycites. Actinomycites are organisms somewhat between bacteria and fungi. The great advantage of actinomycites is that they produce antibiotics. These antibiotics prevent the proliferation of mineralizing bacteria and this prevents the loss of valuable substances. Another thing the actinomycites will do is to prepare the field for the fungi. After this initial heat phase, the temperature drops. The grinders, insects, manure worms, crustaceans appear on the scene and they start chewing up the organic matter. Then the fungi, protected from bacteria by the antibiotics produced by the actinomycites start to multiply. They are now attacking the cellulose and lignin fibres.

Turning the Compost

After about 15 days or when the temperature falls, turning of the compost pile becomes necessary. Be careful that noxious weeds and the rhizomes of stubborn grasses or plants don't get the chance to germinate or sprout. It is therefore important to keep them in the centre of the pile.

After about 5 weeks the pile must be turned again. This is an important phase because it is here that the free nitrogen from the atmosphere is 'fixed' by the micro-organisms. We can mix compost cultures, azotobacter and other nitrogen fixing organisms at the second turn. These organisms like a lower pH though they need a source of calcium to multiply. So together with the cultures limestone powder, crushed egg shells etc. can be added The moisture content should also be checked and water added when needed.

By the end of the 3rd month, the compost should be ready for use.

Water and Air

The pile should be well aerated:

Air is an important ingredient in the compost pile and its presence must be ensured. Never step on the pile or compact it. It would be necessary to create air tunnels especially if the heaps are big. This is done by either putting brushwood horizontally in the middle of the compost pile or putting it vertically every 4 meters to create an air duct. We can try to avoid turning the piles. Drive a crowbar

into the pile and pull it downwards, a semi turning, mixing and aeration can be obtained. This works well with smaller piles. If however, the pile is too soggy and compacted, it must be turned immediately. In fact, in a good composting process an anaerobic phase also takes place. This happens towards the end of the composting process. Too much air also helps the multiplication of mineralizing bacteria, so a cover for the compost is needed not to prevent air penetration but to regulate it.

The pile should be moist enough:

Without water one can hardly speak of a composting process. The materials should be wet and the pile has to be kept moist all the time. Too much water however would lead to compacting and rotting. Also valuable nutrients are lost through leaching when too much water is added. Ideally, the moisture content should be like that of a wet sponge - about 45 to 65% humidity. In the rainy season, sometimes a brown liquid flows out from the compost pile. This can be collected and used as a liquid fertilizer in rice fields. Covering the pile with banana leaves can help against the "flooding" of the compost pile.

The pile should not be too dry also as this halts the fermentation process. When the compost is dry and hot a gray veil appears on the vegetal mass. This is a bad sign indicating loss of substances. One can notice the presence of woodlice. When the fermentation proceeds under ideal conditions one can equally see a whitish- gray veil. This veil is produced by actinomycites and streptomyces, which indicated an excellent fermentation. One has to learn how to distinguish between these two radically different but apparently similar phenomena.

Evaluating the Final Product

A good compost gives a good odour, similar to a fertile soil after the first rain. This is actually produced by actinomicites. Odour is the best discriminating tool to find out if the composting process has gone on as desired.

In a mature compost one cannot recognize the starting materials anymore.

Initially the fermentation process will be acidic but the final product should be neutral to alkaline (pH 7 – 8). If the end result shows an acidic reaction then one knows that something went wrong in the process and little humus will be present. The main reason why we started the composting process is to obtain humus.

A Few Tips:

1. Beware of chemically sprayed starting materials.

Crop residues and soil from fields that have been heavily sprayed with chemical products especially with fungicides will cause serious problems in the composting process, because they eliminate fungi which are very important organisms for transforming the rough organic matter into humus.

2. Do not construct the compost pile near the trunk of a tree. The heat will damage and kill the tree.

3. Never allow weeds and grasses to grow on the compost pile. When there are no shade giving trees one can plant cucumber of pumpkin at the base of the pile. The vines will grow over the pile and keep it protected.

4. Use old compost as a starter for the new pile.

5. In humid climates make smaller piles. This will help aeration. In dry, hot climates make larger ones. This will conserve moisture.

6. Use compost to the tune of 5 to 10 tons per acre.

Composting and Shifting to Organics

Where a lot of chemical fertilisers and pesticides have been used for a long time, shifting to organic farming on the basis of compost could only be a risky adventure. There might be the need for a gradual change including altering the cropping pattern and using indigenous seeds. The usual approach is to gradually decrease the chemical inputs and at the same time increase the organic ones.

For instance, top dressing could be done with a concentrated organic fertiliser. Especially while using green manure for the first time such an organic fertiliser can be of great help. This concentrate can quickly be made in a few days time. It involves a considerable investment as the starting materials are expensive but it will help to maintain good yields and rebuilt a healthy soil very fast.

How to prepare a concentrated organic fertilizer?

In Japan farmers mix rice bran, oil cake, and fish meal preferably at a ratio of 10:1:1. Instead of fish meal, bone meal, blood meal or slaughter house refuse could be tried. To this mixture a source of calcium is added. This can be up to 1% of the total volume. For calcium one can use crushed sea shells, crab and egg shells etc. One can also use dolomite, rock phosphate or other rock powders like basalt for instance. Then microorganisms are applied to the mixture. It is desirable to have as diverse types of microorganisms as possible.

The bacteria can be obtained from good smelling undisturbed soils. This should contain Streptomyces and actinomycites. In good moist compost piles a whitish veil sometimes covers the organic matter. This could be produced by streptomyces. Also bacteria from various fermentation processes can be used. For instance lactic acid bacteria can be obtained from sour milk or curds. Further various yeast can be added. Yeast could be made by fermenting coconut juice. Also cellulose decomposers can be added, for instance, Trichoderma veridi. When some bread with a little honey is kept moist fungi start to grow on it very soon. These are most likely to be Aspergillus types. All other photosynthetic bacteria, actinomycites or commercially available bio fertilisers can be added. If molasses diluted with water at the ratio of 1:500 are added this will enhance the fermentation process considerably. The moisture in the mixture should be maintained by always covering it with the plastic sheet except when it is turned over. The "compost" is turned after 24 hours (in summer). Thereafter, turn the mixture twice a day, and fermented compost will be ready for use in four to five days. Maintain the temperature of the mixture below 45°C.

A foul odour indicates that something has gone wrong. In that case, thoroughly turn the mixture over three times a day. The mixture will become healthy and the foul odour will disappear. If the odour persists, once again the mixture has to be inoculated and kept slightly dry by turning it over four times a day.

In cooler seasons, the time required for preparing fermented compost may be up to two or three times that required in summer. It is very important to turn over the fermenting mixture before it reaches a temperature of 45° to 50°C. When the concentrated compost is ready, it is almost dry. Store it in paper bags. If it is to be stored in plastic bags, further dry it in the shade before filling it in the bags.

Fermented compost, prepared in this way, will easily stay for three to six months. It degenerates only when the water content is too high.

Another much simpler way to make an organic fertilizer is to mix dry chicken manure with crushed oilseed cake, some fresh ashes and if available some rock powder. The proportions can vary according to availability or need. This dry powdered mix is best applied after a rain or irrigation.

Farmers are making various types of liquid fertilizers by fermenting green leaves from different weeds in water. The end product should have a pleasant odour in any case not a bad smell. This liquid is then further diluted with water and sprayed on plants.

Finally maybe the simplest organic concentrated fertilizer is cow urine. Use cow urine diluted in water (1–10) as a foliar spray.

There is a lot of scope to experiment with such fermented products and urine or filtered bio-gas slurry and there are many recipes too

One should figure out how things work and do a few trials on small scale first !

Why is it so difficult to make compost in the village?

One of the limiting factors is the access to water. When people have to manage with 20 litres of water per person per day in the summer, there can be hardly any talk about water for composting. But water can be taken from the village pond and tank.

Another objection raised against composting is that there is nothing worth composting in the village. It is sufficient to look around and you will find plenty of organic matter. People actually burn leaves and "rubbish". Stalks of certain millets are just thrown in the ditches. Enormous amounts of weeds grow all around the villages and on the roadsides. Some aromatic herbs are actually very valuable for the compost pile. Non printed paper torn to pieces, bones, bits of horn and hoof and other animal refuse, especially urine - all organic matter should go to the compost pile.

Further, some say that composting is too costly and too laborious. But leaving organic waste just like that is no solution either. First one has to buy fertility in the shop and that too is not cheap. Second, without proper fermentation process, pathogens multiply in the garbage and infect our health. Again doctors and medicines are not cheap either. We can work every day on our soil fertility. Just 10 to 15 minutes are needed to distribute the ingredients nicely on the pile, fetch some water and keep the pile in good shape. If we cannot work on it everyday then once or twice a week is a must. For that we make sure that the ingredients like dry matter and the dung are kept near the compost place. It will take us just about an hour to keep the compost going.

Again another problem is that the compost is ready at a time when it is not needed. Indeed while it takes two to three months for the compost to mature, the dry season takes 6 or more months. In the meantime our beautiful compost mineralizes and only sand and earth remains. The best thing to do is to use the compost in the irrigated field, vegetable garden or orchard. But for dryland farmers, the compost must be dried in the shade, mixed with earth, covered with soil and kept dormant.

These problems all go together in most villages. Therefore farmers have opted for the following technology: The organic matter is piled up in a pit near the roadside or where there is a water catchment. When the pre-monsoon showers come the rainwater flows to

the pits and the thirsty organic matter soaks up the moisture. The pile is then turned and worked up. In the monsoon the organic matter is piled up at a higher elevation.

For village farmers it is better to reflect upon their present practice of composting. A next step is to find out what resources are available in the village and around and at what effort or cost. Then one can study how ideally compost is made. This paper gives some information, but there are many other ways to produce compost, like the Nadep, Bio-Dung or Nursery Soil methods. After this study the farmers can see how to modify their approach to this very important aspect of soil fertility management which is composting.

Conclusion

Composting is an essential part of soil fertility management. It will be rewarding to spend some time every day for compost work. There are many constrains, but one can find solutions for the problems of composting according to the possibilities the local conditions offer.

Composting is an art and just like any other—it takes time to master.

Green Manure

The practice of green manuring in India comes to us from an ancient agricultural tradition that has withstood the test of time. The Vrkshayurveda mentions the use of sesame as a good green manure plant. Nowadays only a few leguminous plants such as sunnhemp and daincha are used for green manuring. These are usually grown in pure, unmixed stands. However this present practice can have only a limited effect.

In green manuring as in all matters of land use, the golden rule is diversity. Different plants have specific relationships with different microorganisms and they accumulate different nutrients in their tissue. Weeds are usually much richer in macro and micro nutrients then cultivated plants. Datura for instance contains 34.7% of phosphoric acid. Cactii are rich in calcium and thistles are rich in potassium. The greater the plant diversity the wider will be the range of organisms working in the soil and of minerals collected and the more complete will be the effect of the green manure on soil health and soil fertility.

Why Green Manuring ?

The benefits of green manuring are known to most farmers. Studies have proved that crop yields increase markedly after green manuring. Also the quality of the produce improves. It has been found that the vitamin and protein content of rice is higher when it is preceded by a green manure crop (Sundaraj & Devarathinam). Some of the benefits of green manuring are given here below:

- The deep penetrating roots of green manure plants break open the deeper and harder layers of the soil. This improves the movement of air and water in the soil.
- It improves the moisture retention in the soil because of the humus it produces
- Green manure grown with the pre monsoon showers or with residual moisture will prevent loss of nutrients through leaching or nitrification.
- The green manure plants unlock minerals from the vast reserves of the subsoil. These various nutrients will become available for the crops when the green manure plants are returned to the soil, either incorporated or used as mulch.
- The biomass produced by the green manure will become food for all the different soil creatures, both macro-organisms such as, arthropods, mollusks, and earthworms, and microorganisms such as algae, actinomycites, amoebae, fungi, protozoa and bacteria which are the real builders of soil fertility.
- Green manure increases the organic matter content of the soil, improves soil structure and tilth. In sandy soils it binds the particles and makes them more cohesive while it makes clayey soils more porous.
- Some leguminous plants have root nodules containing nitrogen fixing bacteria.

Which plants can be used? Where to get the seeds from?

If we carefully observe the ditches on the roadside, abandoned areas, places overgrown with all sorts of weeds, we will find that the soil there is soft, good smelling, well structured and very fertile. This indicates that a variety of plants—weeds, flowers, cultivated plants—can be grown along with commercially available and commonly used green manures to improve soil fertility.

From one stretch of roadside many weed seeds can be collected in a short time. These seeds are for free. Most of these weeds are unpalatable to livestock, which is another plus point.

Ideally a green manure mix includes, but is not limited to, seeds

of leguminous (pea family), cruciform (mustard family), and composite (sunflower family) plants.

Here is a list of plants that can be used to form a good green manure mix.

common name	botanical name	family
horse gram	Dolichos biflorus	leguminosae
cow pea	Vigna sinensis	
moth bean	Vigna aconitifolia	
sunn hemp	Crotalaria juncea	
daincha	Sesbania aculeata	
kolingi	Tephrosia purpurea	
wild indigo	Indigofera hirsuta	
sunflower	Helianthus annus	compositae
niger	Guizotia abyssinica	
zinnia	Zinnia elegans	
cosmos	Cosmos sulphurus	
coriander	Coriandum sativum	umbelliferae
mustard	Brassica nigra	cruciferae
sesame	Sesamum indicum	pedaliaceae
periwinkle	Vinca roea	apocynaceae
wild mint	Hyptis suaveolens	labiatae
wild cucumber	Citrullus colocynthis	cucurbitaiceae

How to proceed with green manuring?

Mix the seeds of all the plants you have selected and sow them on the land. It is better to apply rock phosphate and a little compost while sowing the green manure. By doing so the bacterial activity and the nodulation in legumes will be stimulated. When the soil is really very poor a mix of green manure plants will not grow very well together. This explains why a single plant is usually preferred in conventional green manuring prescriptions.

But in such cases, line sowing of green manure plants can be practiced. Each line or portion of a line should be sown with one plant species only. In this way we still obtain a diversified green manure stand.

The stand of green manure should be kept on the land for a minimum of one month before incorporating it in the soil. If the green manure is kept for a longer period then it should be cut back when the flowers start dropping to the soil.

Young plants have of course a low lignin and cellulose content. Thus incorporating them will produce little humus. But there will be

an increase in available nutrients for the crop that follows immediately afterwards. Mature plants are much richer in lignin and cellulose and so much more humus will be produced. However to decompose this solid organic matter, energy will be taken from the soil. This can be a serious problem especially in poorer soils. Therefore it might be necessary to either add some compost when this ligneous matter is incorporated, or to add tender immature plants and young leaves. This will ensure a proper release of nutrients in the soil that may be in synchrony with plant growth demand.

Green manure should not be plowed deep into the soil. It must be incorporate it in the top few inches of the soil. The disk harrow is an ideal tool to do this job. If nothing is sown soon after incorporation and thus no feeding roots are present, lots of nutrients will be lost.

Problems with green manuring .... and solutions

Many farmers are disillusioned by the use of green manure. Some explanation of why this is so has already been touched upon above. But there are other factors, mainly in drylands, which will have to be addressed and dealt with. The difficulty in growing green manure in the villages is basically that it occupies the land at a period when a crop could be grown. Farmers cannot afford to "waste" a season just for green manuring. In agro ecological zones with two cropping seasons, there could be several ways out of this hurdle.

One way in which the problem of green manuring can be overcome is to inter-sow the main crop with some selected plant species. These should be spreading types. A very good example of this is the moth bean (Vigna aconitifolia). Pearl millet (Pennisetum typhoides) a summer crop, grows well together with moth bean. The moth bean, usually grown in the winter season, will spread vigorously, gradually covering the entire field. Weed growth is therefore restricted, which is also an important plus point. At harvesting time only the earheads of the pearl millet are cut, all the rest remains in the field as green manure. Here again incorporation with the country plow might be difficult. If no tractor is available, cattle can first be let to graze in the field or sheep penning can be done. Then seeds of the winter crop are broadcast and plowed in.

Other examples of this method are:

- pearl millet (*Pennisetum typhoides*) and horse gram (*Dolichos biflorus*)
- corn (*Zea mays*) and cowpea (*Vigna sinensis*) or velvet bean (*Mucuna pruriens*)
- corn and moth bean or horse gram and cucumber (*Cucumis sativus*).

Different combination with grains and legumes can be tried. We must understood that the legumes in these cases are not grown for the pulses they normally yield, but for green manure.

In bad years, when the rains fail, then of course these plants can be allowed to finish their life cycle and provide for a good pulse crop. A disadvantage of this however is that the corn or sometimes sorghum stalks cannot be used as fodder.

Another possibility is for instance to sow during the winter monsoon or second season when the field is cropped to pulses, sesame and mustard as a mixed crop, one kg of mixed green manure seeds—(*Sesbania aculeata*, *Crotalaria juncea,* etc.)—per acre at the weeding time. The plant density need not be more then 1 per 2m2 . Now what happens? The green manure grows up between the standing crop, it flowers and will produce a heavy crop of seeds. The crops are harvested as usual but the green manure now maturing, remains standing in the field. Over time these plants mature and die, their seeds fall to the ground by themselves and no further attention is needed for the rest of the dry season. The next year, with the coming of the pre monsoon showers, the seeds lying dormant on the soil, sprout and grow. No time or energy is needed to plow and sow the field. The result is that with a few pre seasonal showers, a dense stand of tall green manure plants can cover almost the entire field!

Now incorporating this much of organic matter can be a problem. Cultivating the land with the country plow seems then nearly impossible. One can hire a tractor to do the job. But first compost is brought to the field by bullock cart. The tractor then makes a first run with a disc harrow which flattens the sea of greenery. The compost is then spread and seeds of for instance dryland rice are scattered into the debris. A second run is done by the tractor, mixing most of the organic matter and the seeds into the top few inches of the soil, while a lot of organic rubble is still covering the field as mulch. When the rains come, as can be imagined, a green carpet of vigorous growing young rice seedlings emerges and covers the fields.

This technique of green manuring might not work in all years, sometimes the rains are late. But it is worth trying. The initial investment for seeds is negligible. Furthermore, it could be tried to sow the green manure in lines, together with the crop. Various options can be followed. Non-browsed weeds can be used in places where after the harvest, free grazing of cattle is practised. Hyptis suaveolens and Crotalaria panniculata are good plants for this purpose.

In areas with only one rainy season things are much more difficult. Here a diversified cropping pattern, eventually including lines of green manure plants, can then be followed. For instance millets can be intercropped with lablab beans (*Dolichos lablab*) and pigeon pea (*Cajanus cajan*).

For harvesting, pigeon pea is usually cut and brought home. If instead of completely cutting these plants, they could be pruned removing only the fruit bearing branches, then they would remain alive. With the onset of the new rainy season these hardy plants will run out profusely. Then after sowing the crops, the red gram can be cut and put down as a fertilising mulch.

Again this might not always be possible to follow as red gram stalks are needed for fuel.

Another way out is to incorporate in the cropping pattern, a line of castor plants and jack beans (*Canavalia* species). The castor plants can give a good revenue and will serve as support plants for the Canavalia vines to climb on. Canavalias are very deep rooted and very drought resistant. They can easily bridge over the dry season and produce green foliage in the hottest summer.

In the low rainfall areas of Tamil Nadu farmers grow sunnhemp (*Crotalaria juncea*) on a small part of their land. The sunnhemp will be processed to make ropes. Each year the sunnhemp is grown on a different spot, so that over the years the whole field can come under this particular rotation.

What happens when green manure is incorporated in the soil? As already mentioned green manure must be incorporated in the top few inches of the soil and never plowed under. When green manure is plowed in deeply, it cuts off the capillary action of the soil, thus preventing the moisture to rise. Besides, like a sponge it will absorb the moisture from the soil. Further, an anaerobic process will start and the leaching of nutrients will be unavoidable.

The young roots of plants also have no immediate access to the eventual nutrients plowed in deeply.

Carbon dioxide coming from the decaying organic matter pushes out the air from the soil and hence also the nitrogen. That is one of the reasons why the crops look yellowish after digging in green manure and that, to the discontent of the farmer, nitrogenous fertilizers have to be applied together with the organic matter.

If on the other hand, the green manure is incorporated in the surface layer, where air, moisture and heat are available, free living bacteria start to proliferate on the available organic matter. According to M.W. Federov, non symbiotic bacteria can fix up to 100 kg of nitrogen per hectare per year. H.P. Rusch indicates that nitrogen fixation can still be enhanced if, besides the carbohydrates released from the plants, micro nutrients, vitamin B producing organisms as well as paramecia, amoebae and actinomycites are provided. This indicates the importance of applying some compost as an inoculant together with the working-in of green manure. The nitrogen released

in the process of the decaying surface layers of the soil will be immediately used by the young plant roots.

But it is important that the small quantities of minerals that plants need can be released from the soil particles. According to Faulkner, decomposing plants release carbon dioxide which, in the presence of moisture, is transformed into carbonic acid. Carbonic acid is a natural solvent for plant food minerals. When green manure is on the surface of the soil, the subsoil moisture can rise towards the surface where it meets the carbon dioxide and forms the carbonic acid. Also when it rains the organic sponge structure is able to hold lots of water, run off erosion is minimized and water holding capacity is increased. These added advantages, together with the nutrients contained in the green manure crop itself can provide for the growing of abundant, healthy crops.

Conclusion.

It is advisable to use biofertilisers, such as phosphobacteria, azospirillum, rhizobium cultures, organic manures, and rock powders together with the practice of green manuring. This will have a very positive effect on the state of the soil and will very much benefit the food crop that follows.

A small part of the available compost can be used for sowing green manure and the rest at the time of incorporation.

On very sandy soils better results might be obtained when the plants are used as mulch or if they are first composted.

Nevertheless many constraints remain to the use of green manures—the problem of grazing, cost of plowing, etc. Although some of these problems can easily be dealt with, for some it remains a difficult task. The main limiting factor is most likely to be the lack of moisture.

There are other options and possibilities, somewhat linked to green manuring, such as crop combinations and alley cropping

Part V: Shifting to Organic Farming

There is a worldwide recognition and acceptance that our agriculture needs a thorough overhaul. A change is imperative if, as a species, we want to continue to exist on this (once) beautiful planet.

One of the most harmful operations in agriculture is the spraying of pesticides.

Consumers are now well informed about the hazards posed by pesticides to their well being, to the future of their children and to the environment. There is a growing demand for organically grown produce. People are even willing to pay more, if needed. Many chronic health problems have been found to disappear when people shift to eating organically grown foods.

Farmers also are aware that the use of chemical substances in their daily practice is not without dangers or ill effects. However for them the central questions remain: *What else to do? Is it possible otherwise? Will we not lose our crops? How to cultivate differently? How to go about it?*

Indeed, if farmers have to shift to an environment friendly alternative, not only technical but also, as we have seen earlier, political and social perceptions need to change. Instead of planning for big farms we need to concentrate on small farms, work with small and medium farmers, make land available for the cultivator and stimulate local food production and markets.

For those small and medium farmers who are motivated to "shift" to a low external input and organic agriculture a number of options are available and although every farmer seems to have his own approach, basically two lines of action are in vogue.

One approach centers around the use of bio-pesticides and IPM, if initially not on the entire farm, at least in a part of it. This line of action is called *"Growing without poison"*.

Another approach is to experiment with organic methods on a small plot in the farm, this is *"The trial plot system"*.

Growing Rice without Poisons:

Rice is one of the major staple foods for people in Indian towns and villages. Both quantity and quality of this food is of great importance. Rice pests are a major cause of quantitative losses in produce and the use of poisons to combat these pests brings down the quality. Earlier rice pests were fewer. Today with the introduction of high responsive varieties and the associated heavy use of chemicals, the rice

ecosystem which was once so balanced, has been thoroughly disturbed. Now these is a seemingly endless list of both major and minor pests attacking and sometimes destroying the rice crop.

In the village of Maradur in rural south India, many rice farmers have given up commercial pesticides, which turned out not to be not as effective as they expected. They have instead opted for the use of botanical based pest control measures. This is indeed quite a common situation. Farmers are looking for better ways to control pests but they are not necessarily ready to give up the use of synthetic fertilisers. In Maradur village as well, barring botanical sprays, all the other practices remained unchanged. The problem of pests is first and foremost in the minds of these farmers. However, it should be said that the pest issue is closely linked with a set of other factors such as excessive or wrong fertilization, lack of rotation, wrong choice of variety or the question of water management.

Therefore a gradual but comprehensive change, covering all these aspects is called for. If we follow a methodical approach for shifting to organics, pest damage should by itself diminish greatly and ultimately appear only incidentally.

The issue that stands second in the mind of farmers is the drop in yields and the financial losses it could entail. But crop failures, in spite of the repeated use of dangerous chemicals are occurring regularly. The yellow *Tungro virus* and the *American boll worm*, have ruined many farmers and driven others to despair. All arguments aside, this remains a crucial issue though most experiences have shown that even if yields decline in the initial stage so does expenditure, making ultimately little difference on final account.

Identifying Pests and Predators

How to control pests in an efficient & safe way? Before we answer this question, we must first be aware that there are two types of insects foraging in their rice fields. There are the *beneficial insects* called predators and the really harmful ones which are called *pests*. When farmers spray with chemical pesticides they are sure to destroy these beneficial insects too. Also farmers are sometimes mislead and mistake a good insect for a bad one. Farmers have even sprayed against spiders! Thus the first thing to do is to be as clear as possible on *who is who*!

Therefore—as was done in the village of Maradur—a practical thing to do is to get a sweep net, go to the fields and catch as many insects as possible. The best time to do this is early mornings or in the evenings.

The next obvious thing to do is to find out if farmers know about

these insects and how they evaluate them. For this we take two sheets of paper, one for the *good guys* and one for the *bad guys*. Doing so could lead to intense discussions. It is therefore recommended to have an expert present—a person with an exact knowledge of things. Books, posters or pictures with a description of the predators and pests can equally be of very great help (e.g. FAO poster on Natural Enemies of Insect Pests of Rice). From this exercise farmers often come to conclude that they actually sprayed against a predator insect. Also farmers become aware of numbers, how many pests, how many predators?

If regular checks with the sweep net are done one can come across situations in which as many good as bad insects are counted. If that is so the crop is relatively safe and would not need sprays of deadly poison.

Botanical Sprays

After this identification and counting the discussion is centered around the topic of controlling the major pests without harming the predator insects. Here the first thing to do is to opt for a proven method of biological pest control. This is in most cases *neem seed kernel extract*. Neem seed kernel extract (NSKE) at 4 to 5% will not kill the beneficial insects though some of them might not like it either.

There are always farmers who are willing to do the experiment, just to give it a try. Some farmers will fall out of the experiment and take to the old stuff again. But the results of neem are almost always at par with other treatments. Hence more farmers are likely to be attracted to the safer and cheaper neem alternative.

This is what actually happened in the village of Maradur where ultimately a low cost unit, a rice grinder for obtaining NSKE was set up by an enterprising villager. Farmers from neighbouring villages also realized that this alternative product can be obtained at only a fraction of the cost of conventional pesticides. Besides neem, *Ipomea* leaves are now also being used with great success. The residue from the extraction is used as a supplementary organic fertilizer. In this village neem and Ipomea are abundantly available but in other areas, seed extract of *Jatropha species*, *Annona squamosa* (custard apple), *Derris indica* (pongam), *Bassia latifolia* (madhuca), can also be tried, as well as leaves of *Vitex negundo*, fruits of *Randia dumetorum* or seeds of *Thevetia neriifolia*, etc.

Elsewhere (e.g. in Keeranur) villagers came to the conclusion that a decoction of plants not browsed by goats and cows can be safely used for pest control. However, not all bio-pesticides are safe.

Tobacco leaf extract can be very toxic for humans and should be used only as a last resort. Always wear rubber gloves while handling tobacco juice.

Other Predators

Very often neglected is the *role of birds* in pest control. To attract birds put up a few perches here and there in the rice fields. Traditionally a clay pot painted with white dots is put on these sticks. Drongos and other birds find these watchtowers ideal resting and observation places. The heron, besides implementing a pest eradication programme, manures the field as well. When the destructive chemical pesticides are abandoned, spiders, frogs and lizards too return to the fields. The whole ecosystem starts to recover. The soil undergoes changes too. Earthworms appear and the microbe world booms. When soil conditions improve further with the application of organic manures and when a crop rotation system is followed a drop in pest incidence almost automatically follows and later pests become a minor side issue of the whole agricultural operation.

There are pests of a different kind which create a lot of trouble for the rice farmers. These are the rodents. Rats coming from the surroundings start visiting the fields and attack the sweet tasting stems of the young rice plants. To be save from predators and human sight, rats operate mainly in the interior parts of the fields. Later when the grains start to form and mature, rats "move in" into the field bunds, and start establishing veritable go-downs there. Controlling rodents is thus of as much importance as controlling insect pests. In certain regions, mainly in tribal belts, rat catchers take care of this problem wonderfully well. In other places one can rely on the natural enemies of rodents. Snakes and owls are the main predators of rats in the rice fields.

To talk about snakes with the village folks is a very touchy subject. Though most snakes are harmless, actually they are very beneficial for farmers, there is a very strong prejudice against snakes. Owls are an easier subject to deal with. Perches, put up here and there in the fields will do a lot to control the rodent population with a minimal effort. An owl perch is preferably T-shaped, and is about, 3 to 4 meters high. The horizontal part is white washed or wrapped with newspapers. This pale appearance will be more distinguishable at night when the owls are active. These methods of pest control and the use of botanicals are cheap and simple and easily taken up by farmers in the villages.

Conclusion

Often success in one aspect of the farming operations creates enthusiasm and leads farmers to experiment with other aspects of the farming system as well. In some places farmers were found ready to experiment with biofertilizers and green manure or composting. In other instances farmers have shifted to indigenous varieties. The indigenous varieties give stable yields, without much time and energy needed for pest control.

Introducing the Trial Plot System:

Farmers seem to have become more and more illiterate as far as agriculture is concerned. Who among the rural farmers knows what IR 20 or any such thing means or where it comes from! There is no more connection between the culture of the farmers and the seeds they use. Previously, agricultural knowledge was passed on as a tradition, through rhymes, songs, sayings, certain practices and festivals. Varieties of crops had names which expressed something about their nature. For instance, "jeeraga samba" indicates that the rice is fine, scented and small, just like "jeera", while "samba" indicates the season when it is to be grown.

In certain parts of North-East India, before the rice growing season started, a ceremony—a fertility festival—was celebrated. The rice seeds offered to the goddess of fertility were spread out in the centre of the village. The young girls, traditionally attired, would then perform a dance on the spread out rice seeds. Ever since this practice was abandoned farmers, especially the women, have noticed an unexplainable decline in the vigour and yield of the rice crops. After investigation it was found that a special paste was made to anoint the feet of the dancing girls—and this pomade contained zinc! In this way, the rice seeds in fact received a coating of organic zinc. This stimulated the micro-organisms in the soil and zinc deficiency thus did not exist. This is just one example of farming and culture, now irrevocably lost at the altar of "progress". (Compare this traditional practice with the "scientific" application of 12 kg. of zinc sulphate per acre in our modern times!)

Farmers have always been researchers and innovators, authors and guardians of a tradition of innovation, so to say. Nowadays, agricultural research has been snatched away from the countryside, from the village practitioners and is now hidden in the sterile and freezing rooms of companies.

If the culture of the land must survive, if food security must be assured, it is imperative that the culture of experimentation should return to the farmers once again. There is hope and joy in the fact

that this is what is increasingly happening today among farmers in all corners of the world. Farmers are rejecting commercial seeds and the destructive conventional practices. This resurgence, this renewed searching for alternatives, the reappraisal of what has been lost and this spirit of innovation are sure signs that a new culture is being born—one that links the soil, plants, humans and the cosmos. It is the hallmark of the end of this century.

An excellent tool to reinstitute the spirit of research and innovation is what is called the trial plot system.

What is the Trial Plot System?

This is a simple method which provides guidelines for farmers to experiment with various options or various combinations of them on a small piece of farmland. It avoids the element of risk which is one of the factors hindering experimentation.

The system consists of marking out within the field, two small *identical* plots, one of which is the experimental plot and the other the control plot. In the experimental plot, the farmer will try out whatever he wants to experiment with, while in the control plot he will do exactly whatever he does in the rest of his field.

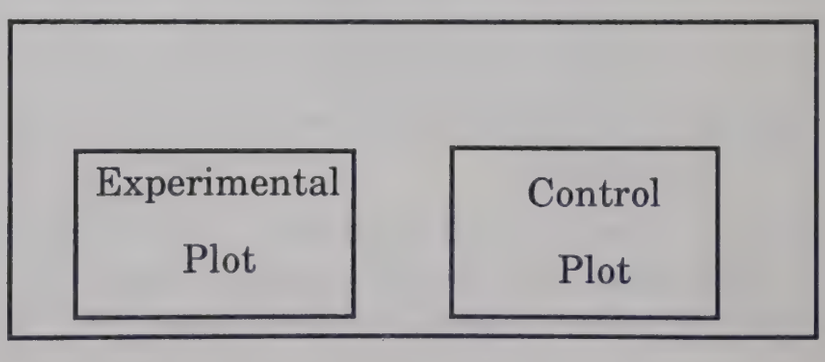
The size of the plots could either be 5 m x 5 m or 10 m x 10 m. Smaller plots could be used for experiments on vegetable crops, but for field crops it is better to use 100 m^2 plots. It is necessary to have both these plots as this makes it possible to compare and evaluate the outcome of the experiment. The weakness of most casual experiments done by farmers is a lack of accurate comparison and proper assessment of the result. With the control and experimental plot of identical size, observations can be made and compared very easily.

How and where to set up Trial Plots?

First select an area in the field where two plots (control and experimental) can be made. The plots can be side by side, but preferably with some separating space (to avoid interference).

The two plots can be adjacent to each other, but this is not a must.

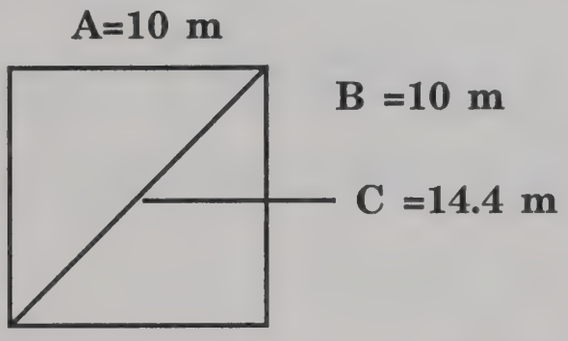
(Fig.1)



• One point to remember is that besides the size of the plots, even the soil condition should be more or less identical. One plot should not be located in a wet or fertile corner and the other in a poor or dry corner of the field, say just next to an eucalyptus tree! Look for an "average" area in the field.

• See that the plots are easily accessible, preferably near a path or a bund, so that the plots can be observed easily.

• One can use any unit to measure and mark out the plots, either a rope or even one's stride, but the measure should be accurate. You can ascertain this in the following way:



(Fig.2)

In plots of 10 m x 10 m the diagonal will be 14.4 m.
In plots of 5 m x 5 m the diagonal will be 7.7 m.
Make sure you have right angles (90^0) in the corners.
This way you can lay a perfectly square plot.

• The plots should be clearly marked off from the main field by a small bund. This is because both plots need to be harvested separately. This is also important for instance, in the case of organic experiments with wet land crops, because irrigation water from the field where chemicals are used must not flow into the organic experimental plot.

What can one try out?

Most farmers have a few things in mind that they always wanted to try out but somehow never got down to. This is a good opportunity for them to "try it out". Some farmers might not have any "ideas" and would need to be guided for the first few trials but once the farmer gets into the 'groove of experimenting", he can continue the learning process on his own, putting his creativity and ingenuity to test. In such cases it is recommended to start with options that are in the immediate reach of farmers.

- For experiments in pest control, neem seed kernel extract (NSKE) could be tried out either or not mixed with cow urine.
- Bio-fertilisers could also be tested.

- Green manuring and composting could come at a later stage.
- At a still later stage, various combinations could be tried, such as, composting and green manure or compost and bio-fertilisers and so on.
- There are a number of non-cash inputs worth examining, like spacing—increasing or decreasing the distance between plants, sowing or planting following the direction of the sun, following the lunar cycle. One can even try to find out if it is really necessary to irrigate so much.

Here is a small list of what farmers have been experimenting with, using this trial plot system:

- Botanical sprays: mixtures of various plants not browsed by animals
- The "Tanjavur kitti" or "bow trap", a traditional rat control method
- Salt water seed selection
- Manure Tea
- Indigenous varieties
- Vermiwash
- Seed treatment with cow urine (1 litre cow urine :10 litres water),
- Wider spacing in rice
- Tender coconut water sprays
- Leaf manure, green manure, compost
- Root pruning of seedlings

Evaluating the Experiment

What to observe, how to monitor, record and compare, are the crucial parts of the whole affair. All hinges on this.

Yield being the foremost (and favorite) criterion for comparison, it is very important to measure and weigh correctly. The yield of both plots—the experimental and the control—must be harvested and of course, stored separately. The unit of measurement can either be by weight or by volume. But to evaluate losses in storage, one has to weigh in kg. One can weigh and compare the two samples after drying, after 3 months and eventually after 6 months of storage. Straw yields are usually measured in bundles.

Besides yield there are other possible variables which must not be overlooked. These are costs/expenditure, labour inputs, germination percentage, weeding frequency, pest incidence. Keeping quality is again an interesting variable. Are there more weevil attacks in any one of the grain samples? Cooking quality could also be compared.

There are, of course, a number of aspects which are difficult to measure and evaluate, such as soil improvement, nutritive value, gain in expertise, independence of the farmer, less headaches and satisfaction with one's own self-sponsored research for the benefit of all.

Trial Plot Case Studies

Case A:
Wetland rice.
Farmer's name: Srinivas, VRP Dist., T.N.

Variety "white ponni". Medium fine quality. The field was cropped to rice twice a year for 20 years with chemical fertilizers. The nature of the experiment was to see the possibility of replacing chemical inputs by organic ones. The trial plot size was 10 m x 10 m.

The Set-up

Experimental Plot-INPUTS	Control Plot-INPUTS
green leaf manure	green leaf manure
bio-fertilizers	DAP & urea
neem cake	complex
rock phosphate	pesticides
ash	

Results

Experimental Plot (10 m x 10 m) **YIELD**		Control Plot (10 m x 10 m) **YIELD**	
Paddy kg. 21.600		Paddy kg. 20.750	
Straw kg. 52.000		Straw kg. 51.000	
1000 grain weight	gm. 18	1000 grain weight	gm. 17.5
COST/BENEFIT		**COST/BENEFIT**	
Income	Rs. 144.60	Income	Rs. 135.50
Expenditure	Rs. 81.40	Expenditure	Rs. 96.50
Net balance	Rs. 63.20	Net balance	Rs. 49.00

Discussion

First of all we can observe that the yield at present in the farmers field is low. This is very common in an area where only chemical fertilizers have been used for a long period of time.

No serious pest attack was noticed in the experimental plot.

The cost of ash includes also the work of applying it to the field.

The yield increased only slightly in the organic plot. The paddy yield was 4% higher and straw yield 1%. The net income however shows a rise of 27%.

It shows also that the thousand grain weight is better in the organic plot than in the chemical plot. This important fact is a common phenomenon and has been observed in all experiments even where results were negative for the experimental plot.

Conclusion

This was a very successful experiment, good results were obtained from the start. This could be due to the fact that the farmer spent more careful attention to his experimental plot. This example is encouraging but should not mislead us as not all farmers obtain such positive results from the start.

Case B:
Wetland rice.
Farmer's name; Thangarasu, VRP Dist., T.N.

Variety "white ponni". Medium fine quality. This field was cropped to rice twice a year with chemical fertilizers. Once a year FYM is applied to the fields The experiment was to test out the possibilities of replacing all chemical inputs by organic ones. The trial plot size was 5 m x 10 m.

The Set-up

Experimental Plot (5 m x 10 m) – INPUTS	Control Plot (5 m x 10 m) – INPUTS
farm yard manure bio-fertilizers rock phosphate neem cake ash	DAP urea complex pesticides

Results

Experimental Plot (10 m x 10 m) YIELD		Control Plot (10 m x 10 m) YIELD	
Paddy kg. 13.250		Paddy kg. 16.100	
Straw kg. 30.000		Straw kg. 40.000	
1000 grain weight	gm. 18.38	1000 grain weight	gm. 17.38
COST/BENEFIT		**COST/BENEFIT**	
Income	Rs. 89.65	Income	Rs. 111.60
Expenditure	Rs. 59.40	Expenditure	Rs. 65.00
Net balance	Rs. 30.25	Net balance	Rs. 46.60

Discussion

Here we can observe a much better per acre yield than in the previous case. But we see a severe fall in yield , both of grain and straw and income in the experimental plot.

Conversely, the 1000 grain weight was much higher in the organic plot. In the organic plot no plant protection measures were taken.

This experiment shows that in some cases a gradual change is called for. Here the use of a botanical spray might have been useful. A step by step decrease in chemical inputs e.g. 75 % first year and a gradual increase in organic inputs would have been more prudent. *This case is very instructive.* It shows that the overall condition of the field and the practices the farmer has followed must be carefully considered and a well-thought of plan for experimenting must be based on this. Here though the loss was severe, this was partially balanced out by the superior quality of the grain of the organic plot, which will be used as seed material for next years crop.

Conclusion

The trial plot method appeals to small and marginal farmers because the risks are minimal. Even if the experiment fails, the loss would amount to only a few kg. of produce. When the trial is successful the farmer can first consider putting a quarter or even half of his field under the "new scheme". If the experiment fails, the farmer can then drop the whole idea or try to find out why or where things went wrong. He can modify his research parameters and try again.

The method appeals also to the NGO trainers and extension workers who are not farmers themselves or have no substantial knowledge of farming. With this method they can easily guide farmers and assist them with the logistics of setting up the first experiment, measuring and helping the farmer to take notes in a farmers diary. A farmers diary is important because it can be a base for reflection once the experiment is over and while planning for a new trial.

In general, the trial plot system allows to plan for an appropriate system to shift to organic sustainable farming. A gradual shift over a period of 2 or 3 years might be necessary.

From these trials, interesting facts appear. For instance, in Rice the 1000 grain weight is always higher in the organic plots. Weight loss in storage for organic rice is about 2% whereas for the chemically grown it is between 6 and 7%. In chillies and vegetables the improvement in shelf life and taste is undeniable and farmers have obtained much better prices in the local market for their organic products (there is little need for certification in local markets). The germination percentage of organically grown seed is also far better. This clearly indicates a much higher quality and vigour of the life force in the organically grown produce.

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The Regeneration of Tropical Soils

By Claude Bourguignon

Throughout the world we can observe a big increase in the erosion of agricultural soils. The problem is serious because there are now a lot of people on this planet. To give you an idea, the earth's area is 15 billion ha., we are 5 billion people, which means we have only 3 ha. per inhabitant. Of this 3 ha. only a quarter ha. is cultivable. The rest is impossible to cultivate because it is either too dry or too cold, too wet or the slope is too steep. A quarter of a ha. per individual is not a lot. The truth is that we are running out of space! This is the first time that humanity is in such a situation. We have virtually no place for any more people! The times of the Far West, when people could colonize new lands, are gone. We have, therefore, no other choice but to learn to manage and take care of what we have.

I remember the saying of Sir Francis Bacon, the founder of experimental science, who said that, if you want to know nature, first of all start to abide by nature. And why must we follow the rules of nature? Because the natural world has been in existence since millennia. The equatorial system, for instance, the Amazonian or the Borneo forest, by the estimation of palaeontologists, has existed since 30 to 60 million years. A system which has lasted out for so long has proved that it is truly perennial. We, humans, have been cultivating the earth only since 8000 years and so must try not to be too arrogant. We must accept that nature's ways are more efficient than ours. We must learn from nature and follow her example to develop a system of agriculture that is perennial. I will speak to you today about soils, specifically on the topic of biology and try to present a rough framework for agricultural production along perennial lines.

What I now propose to do is to take you on a travel from the poles, the north or the south poles, to the equator and do a very simple thing: just look at the depth of the natural soil. I mean soil under virgin forest or wild vegetation. It is very rare now to find soil under a wild system because humanity has destroyed more than 70 percent of the forests of the world. However there still exist on earth some places, as yet untouched by human destruction, where you can observe soil under natural conditions. So if you go from the North or South pole towards the equator, what you see is that the soil depth varies greatly. There is no soil on the poles. Why so? Because there is no vegetation; and there is no vegetation because it is too cold. There are only rocks. On these rocks you will find lichens, very simple plants, that just cover the surface of the rocks (but no soil). Moving southwards, when you reach the forest of pines in Siberia and Canada, what we call the Taiga, the depth of the soil increases.

Then in temperate countries, the depth of the soil reaches a maximum of 10 m. When you come to the desert belt around the world, the soil vanishes because it is too dry. There is no vegetation, no soil; you are directly on the rock. This rock could either be sand or direct rock, but there is no soil. Still further south, the deepest soil of the earth lies under the equatorial forest, between 30 and 40 m. deep. So what is observed is very clear. The depth of the soil is not uniform wherever you go. This strongly suggests that we must accordingly, develop different agricultural practices to suit varying natural conditions. What we are actually doing is precisely the opposite. We follow exactly the same agricultural practices on soils with very different dynamics.

Now we can look at the height of the vegetation over the globe. On the poles there is no vegetation. Then the virgin forests of temperate countries are about 40 m. high. In the deserts there is no more vegetation. Lastly you reach the equatorial forests where you have the highest forests of the world, about 80 m. high. There is a very strong correlation between the depth of the soil and the height of the vegetation. The higher the vegetation, the deeper the soil. This is due to the fact that vegetation creates soil. The soil is but a pure creation by life and that is why there is no soil on the other planets. On Mars, or Venus or Mercury, you don't find soil, you just find rocks, and this is because there is no vegetation. Without vegetation there is no possibility for soil to form.

Another revealing fact is the chemical composition of the soil. In temperate regions, the soils have a high cation exchange capacity but if you go towards the south, in tropical countries, the cation exchange capacity is very low. It is really surprising that the poorest soil of the world supports the tallest vegetation! What the agronomists, however, conclude is that good production of food in tropical countries is impossible because there is nothing in the soil. So they decide to put in a lot of fertilizers in tropical soils, but this costs a lot of money. On the contrary, what we must do first of all is to understand how the highest plants of the world are able to grow on the poorest soils. If the soil is poor and if the vegetation is tall and lush, it simply suggests that fertility must be traced not to the soil but to another source.

Let us look at how the soil creates an exchange capacity. To create an exchange capacity you must have two things—clay and humic acid. Clay comes from the transformation of rocks by plants. Plants attack the rocks and produce clay. Insects and animals attack leaves and the rest of the vegetation and produce humic acid. It is the blending of clay and humic acid that produces cation exchange capacity. In tropical systems you find very bad clay and very little organic matter in the soils. This is because 90% of the organic matter is

present in the vegetative canopy of the forest, with only 10% within the soil. In temperate countries, on the other hand, 60% of the organic matter, occurs within the soil and only 40% is in the vegetation. These soils are thus very rich. Such soils are able to hold and maintain fertilizers if they are added, whereas in tropical countries fertilizers would be lixiviated (leached) very fast.

The lesson to be learnt is to follow what happens in the forest and do what the forest does. Instead of maintaining its nutrients within the soil, the forest channels them into the trees. This is made possible by deep root systems. Trees of the tropical forests have the deepest roots in the world. Such an efficient system of roots is absolutely essential in order to prevent loss of elements by lixiviation. This is especially so in equatorial and tropical countries with high rainfall of between 3 and 10 m. Imagine the state of the Amazonian forest, for instance, if it were to lose 1% of its nutrients every year! It would be impossible for it to sustain itself if it lost its elements. The fact to be noted is that forests lose absolutely nothing. They maintain everything by a very efficient recycling of elements from roots to the top of the trees. So if you examine the soil for nutrients you will find nothing. You must study the elements in the forest cover.

The expansion of modern agriculture is normally preceded by the burning of forests. This means putting all organic matter into mineral form. With the onset of the rains all the nutrients are lixiviated and nothing remains. Erosion begins immediately and you lose your soil. The worst thing you can do in equatorial and tropical countries is to use the burning system to cultivate because you then immediately expose your elements to lixiviation, especially with the high rainfall. The first thing to do when you want to transform a wild forest of an equatorial country into agricultural area, is to avoid burning organic matter. The correct way to proceed is to just cut the trees, keep the trunks for use, keep all the leaves and all the organic matter on the soil. Then you must directly sow in this organic residue. In tropical countries, you must develop what we call the "non tillage" process. In the temperate countries the inverse is recommended. In the north, tillage is necessary in order to aerate the soil because the turnover of organic matter is extremely slow. As you go towards the south, you must use the non tillage process because organic matter goes so quickly into the living system. We will now see how a non tillage process can be adopted in tropical countries to develop a system of agriculture which is perennial.

There is no sense in using chemical fertilizers because they are sure to get lixiviated. We then have two possibilities. If you start from a wild system, you have a rich supply of elements in the forest cover. I have made measurements in the Amazonian Forest in Brazil

and found, in the forest cover, more than one ton of Nitrogen per ha., more than 800 kg of Potassium, more than 600 kg of Phosphorus, and 500 kg of Magnesium per ha. If you examine the soil, on the other hand, you find absolutely nothing—just about 0.1 ppm of Potassium, 0.01 ppm of Phosphorus and likewise. This would imply that it is impossible to start agriculture. The fact , however, is that all the nutrients are present in the foliage, in the trees and not in the soil. So in the non tillage system, we cut down the forest, then we make a direct sowing of what we call a "pump plant". In Brazil we use plants which are able to grow at the speed of 5 cm per day for roots, and 5 m. in 60 days for the stem. In this way we are able to produce 90 tons of organic matter in 60 days. Afterwards the pump plant is destroyed and in this organic matter we start to sow paddy. We use a machine which is able to sow directly into the organic matter. So we sow the paddy in 90 tons of organic matter. We use rainfed paddy in Brazil because there is no possibility of irrigation. With this system, we start to produce 2 tons of paddy per ha. and reach, within 3 years, a production of 5 tons per ha., without fertilizer.

What is very delicate is to get the time factor right for sowing (within 6 days after the start of the rainfall). If you wait for one month, like a lot of people do in tropical countries, for the soil to get moist enough before they start to sow, you lose the start of the rainy season. What happens then is that the mineralization of organic matter starts very fast. I have measured, a week after the first rainfall, the biological activity doubles—just within one week! So if you wait too long, all organic matter is rapidly mineralized by microbes, all the nutrients go very deep in the soil and when your seed sprouts, it has no time to chase the elements which are quickly leaching away. You must therefore be extremely careful about when you sow your seed. After the paddy crop is harvested, in Brazil, you again have a dry season. During this period you must sow a "pump" plant which is adapted to grow with only 300 mm. of rain in order to avoid leaving the soil uncovered in the dry season. An exposed soil during the dry season will kill all the biological activity. So, during the last week of the rains, you should sow a pump plant. Then the same cycle is to be maintained—you sow paddy or soya bean and so on. Every time you produce a crop, the role of the pump plant is to absorb, very quickly, all the elements which are otherwise exposed to lixiviation after the harvest. This is possible by the special ability of the pump plant to penetrate the soil very, very quickly. In Brazil, from 90 tons of pump plant we have obtained, in organic form, 200 kg of Nitrogen per ha., 150 kg of Potassium per ha., 90 kg of Phosphorus and 60 kg of Magnesium. We thus try to create a sort of copy of the forest.

When you start from an eroded soil, it is a different situation.

You have nothing in your soil, all the nutrients have been lixiviated. The soil is absolutely destroyed. It is impossible to start agriculture directly without putting in something. You cannot possibly plant a forest, wait for it to grow, and then cut it down before starting agriculture. This takes too long. In such a situation we are absolutely obliged to add fertilizers in order to get the organic system going. But what sort of fertilizers? We use the most stable fertilizers available in the market. For instance, for nitrogen we use Urate (sodium) for phosphorus we use natural phosphate (calcium phosphate), for potassium we use silicate potassium (a very strong form of potassium), for magnesium we use dolomite (a carbonate of Magnesium), for calcium we use lime stone. We are obliged to bring in these very stable forms of fertilizer and then we produce a pump plant. After this we can start the same process again—paddy, pump plant...and so on. By this very simple system of using a pump plant we can avoid strong lixiviation which is the problem with all tropical soils. Generally, on an eroded soil, to create a porosity we are obliged to plough the soil very deeply once, for establishing the pump plant.

What we must understand is why this system is so efficient? How is it possible to produce 5 tons of paddy with this system? It is a fact that if we compare the biological activity within this system with the conventional, chemical system, there are considerable differences. I have made comparisons between the wild forest in Brazil, the modern, intensive, chemical agriculture and the pump plant system and found that in the pump plant system there is half the biological activity of the forest while in the chemical system there is only one tenth. With the pump plant system we are approaching the equilibrium of the forest. We have so far only 3 years of experimentation behind us. Probably after 3 to 5 years we will be obliged to put in a minimum of fertilizer because it is impossible to obtain zero lixiviation under any harvest system.

I am quite sure that with this system, we can protect our environment more efficiently than with the conventional system which actually destroys the soil. This is because, when you put organic matter on tropical and equatorial soils it invites a good development of soil fauna. In fact, the total of the porosity of the soil is created by the soil fauna. In equatorial countries, this is specifically the result of termite activity to a great extent and worms to a lesser extent. Worms are very important in temperate counties or in Mediterranean areas. For termites to survive they need organic matter for food. If there is no organic matter on the soil the termites disappear, the porosity of the soil consequently vanishes and when there is strong rainfall it is unable to permeate the soil. The rainfall being very strong in tropical and equatorial countries, there is a difference between the intensity of the rainfall and speed of the movement of

water in the soil. If the soil is unable to absorb all the water it immediately causes saturation and the topmost part of the soil is washed off with the water. I have made comparisons in Brazil between forest systems, with cultivated systems, and found that the speed of water inside the soil is 100 times higher in the Amazonian forests than under the cultivated system. It is not a difference of merely 10 or 20 % but 100 times better! The porosity of the soil of the Amazonian forest is 80 %. This means that you have 80% of porosity (vacuum) and only 20 % of sand and clay. In fact, in Amazonia and Congo the soil is composed of 80% clay. With a high level of clay, the soil would normally be extremely compact but because of the activity of soil fauna the porosity level is as high as 80%. I remember a day in Amazonia when we had a rainfall of 500 mm with a peak of 150 mm. in one hour and it was extraordinary to walk on a forest floor that was not even slightly water-logged or slushy! In cultivated areas such rainfall would definitely have brought about strong erosion. If you fly over the Amazonian forest, all the places where man has followed bad cultivation practices are clearly visible by the orange colour of the rivers. On the other hand in a wild system you have absolutely transparent water because the system is without erosion. Fauna is thus extremely important especially in tropical countries. You must develop soil fauna.

I have studied the microscopy of soil from a tropical system and examined porosity due to termites. What is extremely interesting is the fact that in the Amazon all the soil upto a total depth of 30-40 m is made by termites. The excrement of termites is extremely solid, resistant to erosion and builds up the soil year after year. Soil is after all a biological system. If you have no fauna you are sure to have erosion. This is exactly what can be observed in Europe which is facing a strong problem of erosion. During the 70s, in Europe, we were losing 20 tons of soil per ha. per year, but now the loss is 40 tons per ha. per year. We have doubled our erosion. This is because we have lost our soil fauna. The normal population of worms in Europe should be between 1 and 3 tons per ha., but what we actually find in an intensive agricultural system is only 100 kg. Consequently the soil is not aerated and when it rains we have strong erosion. All the rivers of Europe, which once carried clear and transparent water, are now turbid.

A worm eats its own weight every day. If you have 3 tons of worms per ha., they would eat 3 tons of soil every day. In a year they would eat 1000 tons of soil. That means 10 cms. of soil moves through the worms' system. They produce extensive galleries. A big worm, in Europe for instance, produces 5000 km of galleries per year and the little worms between 100 and 300 million km per ha. per year. This is because the little worms eat dead roots, replace them

with air, thus creating porosity and enabling water to percolate. The importance of soil fauna has been underestimated. There are very few people who have studied termites, for instance. We must understand that without fauna it is impossible for water and for gases to penetrate the soil. The less the soil fauna, the more exposed is your system to erosion. We must develop ways to build up fauna and the pump plant is an extremely efficient method for developing fauna in your soil. The more you have fauna the better will be your soil.

Soil fauna is not only important for water circulation but is also important for oxygen which is necessary in the soil because plants can assimilate only oxidized forms of certain elements. For instance, nitrogen is not assimilable by plants as ammonia but as nitrate, sulfur as sulfate, phosphorus as phosphates. These transformations are done by microbes. Oligo elements which are not soluble in oxidized form are transformed by microbes through a process known as chelation into forms which are assimilable by plants. For e.g. microbes convert iron, using organic acids, into what is called a "chelate" which is an acid form of iron. So if you want microbes to produce nitrates, sulfates, phosphates or chelates of oligo elements, you need oxygen and only fauna can bring oxygen into the soil.

If you have no oxygen in the soil because you have destroyed your fauna by a lack of organic matter or by an excess of pesticides, an inverse reaction takes place. Badly aerated soils lead to the development of anaerobic microbes which, in fact, transform nitrates back into Ammonia, sulfates into sulfur and phosphates back to phosphorus. With this depletion there is no possibility for plants to grow and the use of fertilizers then becomes obligatory. Of course, the industries produce nitrates, sulfates and phosphates but these come with a price. In nature, on the other hand, as products of biological reactions, they are absolutely free. You pay nothing for them.

There is thus, a complete system operating: you have soil containing clay and humus (which means exchange capacity), you have microbes which produce nitrates and other nutrients, and fauna for producing galleries which aid the free flow of water and oxygen. It is only the undisturbed functioning of all these components that ensures good production and a perennial system of agriculture. By just adding fertilizers you cannot hope for a perennial system. On the contrary it leads to erosion and you are more likely to lose your soil. Incidentally, the desert area of the world is increasing at a rate of 20 million ha. per year. At the beginning of the century, deserts were spread over 20% of the earth, but now they cover more than 30% and are increasing rapidly.

I will now talk about how plants feed in the soil, and how is it that incredibly large trees can grow on the poor soils of the tropics and the equator.

Firstly, we do not realize that plants don't primarily feed in the soil but in the atmosphere. If we look at the nutrition of plants we find that soil is the source of only 5% of the dry matter of plants. It is the atmosphere which provides the main part of the food that plants need. It is therefore not necessary to use fertilizers simply because plants need very little from the soil. The atmosphere is the source of 95% of the dry weight of plants, comprising only 3 elements—Carbon, Oxygen and Hydrogen. So the bulk nutrition of plants (95%) comes from the atmosphere. We generally believe that the greater part of the plants' nutrition is derived from the soil, but it does not come from the soil, it comes from the air This is why tropical countries have the best productive potential of the world. You get more sun than Europe and therefore must have higher yields than in northern countries, because the sun is responsible (through photosynthesis) for 95% of the dry weight of plants.

Of the 95% that a plant takes from the atmosphere (to build up its dry weight), Carbon constitutes 44%, Oxygen 44% and Hydrogen constitutes 6%. Carbon and Oxygen come from Carbon dioxide which is transformed by photosynthesis in sugar (sugar represented by cellulose, lignin and by all the different plant sugars). It is not necessary to do anything to bring Carbon dioxide in the atmosphere because this comes by very normal processes. If the sun shines bright and people respire as they always did, to grow plants should not be a problem! In fact the industry which produces a lot of carbon dioxide by burning petrol and coal, could actually bring a huge increase in yield! It is generally believed that the increase in world temperatures is due to an increase in carbon dioxide emission. This is not so. The problem is more a result of increased desertification—the growth of areas where no photosynthesis takes place any more. Every year 20 million ha. of land are lost to expanding deserts. The problem of the increase in world temperatures is thus directly connected to desertification and not to cars or to the industry.

There is a legend in France, told by Jean de la Fontaine, which tells the story of animals attacked by the plague. The lion, the king of animals, calls for a meeting to discuss the crisis. Addressing the gathering, he asks, "Who is responsible for this plague?" In reply, the elephant says "I'm not responsible," the crocodile says "I'm not responsible" and likewise every animal denies responsibility. Towards the end they see a poor donkey, pounce on him, accuse him of being the culprit and decide to kill him! This is exactly what we actually do! We blame the cars for the destruction of our atmosphere. This is absurd because the actual reason is that we destroy our vegetation.

To come back to plant constituents, as mentioned earlier, hydrogen forms 6% of a plant's dry weight. Hydrogen is, in fact, the most common of all elements and constitutes 95% of the whole universe. It

is however very light. Twelve hydrogen atoms are equivalent, in weight, to only 1 of carbon. Owing to its lightness, it represents only 6% of the weight of plants and it is derived from water. During photosynthesis, water is transformed into hydrogen which is used for sugar production and oxygen which is used for respiration. So, in fact, by adding absolutely nothing, 95% of a plant is produced simply by being exposed to the atmosphere. To build up 95% of its dry weight, a plant just opens its leaves in the direction of the sun. If you see it this way, there is a lot of hope in agricultural production.

A fresh plant, however, contains 80% water, which is absorbed through the roots. This implies that in dry countries plants cannot survive. Although some soils of the Sahara, the sierozems, for instance, are very rich, they cannot support any vegetation because of the lack of water. The limiting factor here is not soil, but water. Life needs water. This need for water is, of course, only during the production of the plant. The seed contains only 15%-20% water. Once the grain is harvested, the rest of the water is recycled back into the living system.

To get the remaining 5% from the soil, the plant has to exercise much more. For the plant it is more difficult to take this 5% from the soil than to take 95% of elements from the atmosphere. It is obliged to produce a lot of roots to feed in the soil. To give you an idea, if you take just one wheat plant, the area that is exposed to the sun—the area of the stem and leaves—is 5 sq. mts. but if you measure the area of the roots, it is 1000 sq. mts.! It takes 5 sq. mts. to produce 95% but 1000 sq. mts. to produce 5%! The roots of just one plant of Rye extend upto 400 km and this is made in 6 months! Roots are a fantastic phenomenon. We tend to overlook the importance of roots. We haven't studied them well enough. As humans, we have the peculiar limitation of receiving more that 90% of our information through the eyes. We notice and regard as important, only what we can see. We cannot see roots. It is beyond our senses to identify 400 km of roots within the soil and so we consider roots to be unimportant. In France the deepest roots we have measured are under a cherry tree and extend upto 150 m. deep. This means that trees always go directly after the deep water. They don't care much about dry soil conditions. For such studies we take the help of people who are specialized in exploring the underground. They use special lights and trace the depth of the roots which we eventually identify.

The problem plants face in feeding from the soil is that they can only take elements in a solution. This is actually the big source of problems for plants. They can absorb elements only if they are in a solution of water. This means that they are forced to fight a physical law—the law of concentration. The law of concentration states that in each part of a living cell there is a tendency to maintain an equiva-

lence of concentration inside the cell with the solution outside the cell. This means that if, for e.g., a plant needs a substance like nitrate, it would only be able to get negligible amounts of it, in proportion to the low concentration of nitrates present in the soil. It is impossible for plants to accept the law of concentration. They must fight against it. This is in fact, the characteristic of all life. All mammals do the same. All living organisms do the same. You do the same too. Plants overcome the physical law of concentration by a very intelligent system. They create an electric force. I will explain how they do this.

It is known that the earth is composed of 106 known atoms which physicists have classified. The first category (in the Periodic Table), mono-atomic cations, are atoms with a positive charge, like hydrogen, lithium, sodium, potassium, and so on. The living system takes these elements directly, in atomic form, and retains them inside the clay-humus complex, as what is called the Cation Exchange Capacity of the soil. These elements are retained in the soil because the clay-humus blending has a lot of negative charge, thereby allowing elements with a positive charge to be attracted and held. By this process, acidic soils retain a lot of hydrogen, while basic soils hold a lot of potassium, sodium, calcium, magnesium, and so on. After this what do plants do? If you put a micro-electrode through the membrane of a plant cell you will cross a portion of the cell which has a plus charge and then reach the inner part which has a minus charge. This plus charge is taken from the soil (from the clay-humus complex) and brought into the cell membrane by a very intricate process. Plants have to expend a lot of energy for this. By photosynthesis, they send sugar by the decreasing sap in the direction of the roots. With this energy of sugar they produce a lot of what is called ATP—Adenosine Tri Phosphate—which, in turn, plays a major role in the uptake of positively charged elements. When the membrane is thus suffused with a positive charge, the plants then wait for microbes to produce nutrients with a minus charge. Normally nitrate will never enter the cell owing to its very low concentration in the soil. But now, because nitrate is negative and the cell membrane is positive, this electric force draws the nitrate towards the plant cell membrane. Then, by means of a selective transporter the nitrate is absorbed inside the cell. By this extremely clever system, the plant manages to absorb nutrients like nitrates, sulfates and phosphates from a soil in which these normally occur in very poor concentrations.

When the plant has finished flowering, it stops taking food from the soil, the roots are no more energised, they stop attracting positive charges and what we call translocation occurs. The nutrients from the stem and leaves go in the direction of the roots and potassium, magnesium and so on are returned back to the clay humus system.

In effect, no exportation of potassium or sodium occurs when you harvest paddy for instance, because it is ripe at the time of harvest and gives back all its potassium to the soil. It is therefore unnecessary to bring back potassium in your soil after paddy production. This is, of course, as long as you don't lose your potassium by erosion. You must, for this reason, maintain the clay in your soil.

The cycle of erosion normally starts when you stop putting organic matter in the soil. When the humus content drops, clay begins to wash off very quickly with the water because it is very sensitive to water erosion. Water is a peculiar liquid with both plus and minus charges. However, there is a kind of polarization of the water molecule with a plus charge on the hydrogen atom. Clay, being negative, is thus attracted by water. If you stir soil into a glass of water, the clay tends to remain in suspension because it is attracted by an electric charge to the water while sand and other particles sink to the bottom. In good conditions, when the clay and humus content is balanced, they are held together in a tight bond and are therefore not attracted by the water. On the contrary, if you burn your forests or your straw, you destroy the humus content, consequently bringing down the cation exchange capacity and then you are compelled to replenish potassium in your soil. In traditional systems of agriculture, the erosion of agricultural soils was generally avoided by producing humus (by composting) and by importing good clay, or marl, for instance, which is a very rich form of limestone with a good clay content. Calcium is very good for binding clay and humus together. By bringing in good clay with calcium and by adding compost it is possible to create a system whereby fertility of the soil is maintained. This is what we have totally forgotten in our modern agricultural system. We have forgotten how to feed the soil. We just feed the plants. If we feed the soil, it is necessary to only compensate for the elements that have been exported with the seed. This need can, to some extent, be fulfilled by growing plants like soya bean, which are nitrogen fixing. It is possible, in such a manner to develop an organic system with extremely low inputs of fertilizers in the soil.

Now let us look at the different levels of fertilization.

Fertilization must occur, firstly, at the level of the soil, next at the level of microbes, other soil fauna and lastly plants. If you work correctly, it would only be necessary to bring in what has been exported with the plants, provided the rest functions well.

The reason for fertilizing the soil is to improve its cation exchange capacity, i.e. the capacity of the soil to retain positive charge. We must fertilize microbes because they convert elements into oxides like nitrates, phosphates and into chelated forms. To produce these nutrients, they need oxygen, and soil aeration is brought about by other soil fauna. It is therefore also necessary to stimulate the

growth of the living organisms of the soil. If activity at these levels is optimum, cultivating plants could be very easy.

The first step is thus to improve the quality of your soil. In order to do this you need to know what you have in your soil. A proper soil analysis is essential; not just a study of the clay content but also the quality of clay. If you, for instance, decide to start growing vegetables on a very eroded soil, you need to bring good clay into it. You can transport vertisols, for instance, which have a high content of good clay.

In the Middle Ages in France, people used to transport between 2 and 30 tons of clay per ha., depending on what they intended to grow, to improve the quality of their soil. For instance, the famous Bordeaux wine was made from grapes grown in very acid soils that were improved and made suitable by adding clay with limestone. By this they were able to increase the pH from 4 or 4.5 (a level impossible for growing grapes for wine) to a pH of 5.5 or 6. Now Bordeaux wine is one of the best wines of the world. So, there is a possibility of improving even soil that is really poor by enriching it with good clay

The quantity of clay depends on what you want to produce. If you want to grow vegetables you don't need to cover very large areas. I have been working in the North of Burkina Faso on very eroded soils. To grow vegetables for a family you just need an area of 300-500 sq. mts. For this, we transport clay manually because the people have no other means and no money.

We first prospect an area to find out where the good clay occurs. We have a way by which we measure the quality of the clay, and if we find clay of good quality, we transport it to small patches for vegetable growing. We then use organic matter to produce compost. By mixing together clay and compost, we boost the cation exchange capacity of the soil, making it ready for agriculture. This is how it is possible to start agriculture on very, very poor soils.

In France, for instance, we have prospected the whole country for clay and found some deposits with 300 m. of very good clay. So we know that we have a lot of clay with which we can improve a million ha. But in a large country like India, you have probably not completed prospecting the entire country for its clay deposits. I do not know if this information is available in India. But there is a very big reserve of clay all over the world.

To improve your microbial activity you must concentrate on the 3 big families of microbes.

The family that produces humus comprises mainly mushrooms. To improve this family, you must produce compost because composting involves aerobic fermentation (which is due to mush-

rooms). When you bring compost, you will bring a lot of mushrooms and a huge quantity of microflora which will be able to transform the organic matter of the soil into humus. The main problem is that when you put organic matter in your soil, you have three possibilities. If you have good aerobic soil conditions you can have humification. This is the dominant reaction if the ratio of carbon and nitrogen of your organic matter is very high.

The other possible reaction is mineralization. This reaction occurs when the ratio of carbon and nitrogen in your organic matter is very low. For instance, in the forests, the organic matter has a very high ratio of carbon and nitrogen and that is why forests produce very large quantities of humus. The inverse reaction takes place if you, for instance, put a lot of cattle manure which has a very low ratio of carbon and nitrogen. If you put too much cattle manure in comparison to straw or leaves, you increase mineralization. You must therefore avoid this if you have very low organic matter content. If your soil, on the other hand, has a high organic matter content, then it can improve the process of humification. But the general problem with tropical soils is the low levels of humification. To remedy this you have to bring in organic matter with a very high carbon-nitrogen ratio. Nature, of course, provides for this by ensuring that the carbon-nitrogen ratio increases as you go southwards.

Considering this it is foolish to bring cattle of the north of Europe to southern countries because they are unable to digest tropical plants which have a very high carbon-nitrogen ratio. Instead, it is much better to use animals who have a special species of mushroom in their stomach which help to break down plants with a high lignin content. As you go towards the north, the cellulose content in plants increases while southwards, the lignin content gets higher. In the south lignin is important because it produces a lot of humus.

Another process of transformation of organic matter is that which takes place under anaerobic conditions—fossilization. For instance, if your soil has a very bad structure, and you put a lot of water on it, oxygen can enter into it only with great difficulty, or if you make compost and compress it, you create anaerobic conditions which give out a very bad odour. In typical anaerobic conditions, ammonia and sulfur and so on are released, which smell very bad. In such conditions it is absolutely impossible to produce humus. Mushrooms are microflora which cannot survive anaerobic conditions. They need aerobic conditions to live. So if you create anaerobic conditions in your soil or compost, you immediately start the process of fossilization of your organic matter. Under irrigation, in paddy, for instance, the organic matter is maintained, it cannot get lost, because you put your soil in anaerobic conditions and allow fossilization of the organic matter. However, with this process you will get an or-

ganic matter of poor quality. In Venice, for instance, all the buildings rest on logs of wood since 8 centuries, but they have not collapsed because the logs are under water and it is impossible for mushrooms to destroy them. Wood can remain undestroyed under water for thousands of years.

You must, however, avoid anaerobic conditions by developing soil fauna, thereby ensuring good aeration. Under aerobic conditions, on the other hand the two possibilities of humification and mineralization are both important and must be developed—humification to protect your soil and mineralization to feed you plant. You must maintain an equilibrium between these two processes.

So, to stimulate humification you must use compost. If, for instance, after an irrigated paddy crop, you have a dry season during which you will not be irrigating, instead of leaving the field exposed, you must start mineralization once again, in this case by green manure. Green manure is a very young plant that must be cut back just before flowering, at the moment when the carbon-nitrogen ration is very low. By this method, humus is not produced but the microbes of mineralization are stimulated very, very quickly.

Generally in sandy soils you have a very intensive mineralization. Never use green manure on sandy soils. On clayey soils, where the movement of organic matter is very slow, you can use green manure. For sandy soils, use only compost because the reaction of mineralization is really too fast.

The population of microbes present are essentially for mineralization. You must go slow. That is why, on sandy soils in tropical countries, we consider it important to keep a minimum of shade, a hedge around your field, for instance.

In Java, they have developed a very clever system. They have big trees around the houses and then the size of the vegetation decreases slowly. They use all the light available and grow several kinds of vegetables under the shade of even the big trees around the houses. In temperate countries it is very different and absolutely impossible to produce vegetables in the shade because the sun is the limiting factor.

There are, however, a number of tree species which permit cultivation under them. In very dry areas like the north of Burkina Faso in Africa, we use an Acacia species—Acacia albida—which develops leaves in the dry months and sheds them in the rainy season. So it is very easy to cultivate under trees like Acacia albida. In the dry months when you have no crop, it has all its leaves which are very rich in nitrogen. It is a nitrogen fixing tree. In the monsoon there are only bare branches which make it very easy to cultivate below them.

The third class of microbes which you must stimulate are those

which live in the root zone of plants—the rhizospheric population. To stimulate this population, you must use different species of plants. This is why, rotation must be practiced. You must avoid repeatedly growing the same crop because this will stimulate only the same species of microbes. For instance, if you concentrate only on the family of Cruciferae, they use a lot of sulfur and greatly stimulate the microbial population of sulfur and year after year if you grow mustard for example, too much sulfur will be consumed, eventually leading to a depletion of sulfur reserves. You must therefore change your crop in order to change the rhizospheric population.

For annual plants you must practice rotation while for perennial plants you must use association. There are very few agronomic studies on the topic of association, but we do know that there are a lot of species which can grow together well and there are also those which cannot. For instance, in a vineyard, peaches have a very good association, but this is not the case with apples. Peaches in vineyards improve both the perfume of the peach as well as the perfume of the wine. We do not know exactly why. It probably has something to do with the secretion by the roots. There are very few such studies. In vegetables, if you plant strawberries with onions or garlic, there is an increase in the perfume of the strawberries. On the other hand, beans and onions are very bad companions. It is very interesting. We do not know what really occurs. It is probably because half of the photosynthesis goes through the roots by what we call root exudation. To feed together, the plants send a lot of exudate into the soil and the microbes which are along the roots use this exudate—sugar, amino acid, lipid and so on and in exchange the microbes transform elements into nitrate, sulfate and so on. It is a very close association.

There is a very good study made by the team of Timonin from Chicago University (Timonin 1950). They have used an artificial medium—just water — to cultivate plants. They create a deficiency, a specific deficiency in oligo elements, for instance, in zinc or manganese or copper and then they take the roots of the plant with just the sand around the plant and put it in the soil and observe an increase in the population that form the chelation of zinc or manganese or copper. This means that when a plant has a deficiency, it secretes a specific exudate to stimulate the function of the microbes that they use. That is the reason why you absolutely need a good population to answer to the exudate production and that is what we call the rhizosperic population.

Plants are cleverer than we think. They are even able to change the texture of the soil. For instance, plants which grow in sandy soil are able to adapt themselves by a very intelligent method. They accumulate clay around their roots, while all around them there is sand. When you do a microscopic study of the roots, you find them totally

covered with clay (Greenland 1979). This is a very local transformation of the texture of the soil. Inversely, in very dense, clayey soils, there are plants which are similarly well adapted. They, in fact, produce sand! Calcium oxalate is a sort of crystal produced by plants which effectively pushes the clay away and this creates space between the clay and the roots to let in water and air (Callot 1982). This is how plants survive in clayey soils. Around the roots you also find very special populations of microbes which are able to transform the pH, texture and so on.

To recapitulate, you need to have a good population of fauna in your soil because you need good aeration and you need good water circulation. To obtain a good faunal population, you need a high level of organic matter for which you can use compost. You must avoid using pesticides because they destroy a lot of worms, acarians, small insects of the soil and so on. You must in fact protect your faunal population. So if you correctly fertilize the 3 levels—soil, microbes and fauna—then normally, for plants, the only thing you have to do is to bring back what you have exported. If you grow beans, it is not necessary to bring back nitrogen because beans produce their own nitrogen. If you grow paddy, it is not necessary to bring back potassium because there is no exportation of potassium. You only need to return what you have exported. Normally, if the whole system works efficiently and you have a deep root development, exportation levels will not be high.

We generally believe that it is necessary to put a lot of things in the soil. Look at the forest which needs only 20 kg of nitrogen per ha, about 20 kg of phosphorus ad 30 kg of potassium to produce huge trees of 90 m. height. The needs of nature, by luck, are very low or else the earth would have been covered with deserts by now.

If a soil is dead, however; and I have seen enough soils over the world to be able to tell that a soil is dead, it would be impossible to produce plants without fertilizers. You have first to start life and then you can decrease the quantity of fertilizer. But on a dead soil it is impossible to produce directly, because nothing functions.

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The Contribution of Soil Fauna—Especially Earthworms—to Soil Fertility

By Sultan Ismail

Earthworms, by virtue of their activity, contribute physical and chemical alterations in the soil, improving soil quality and plant growth. They therefore have always been regarded as friends *of the farmers.*

Earthworms form a major component of the soil organisms, and they along with a large number of other organisms constitute the soil community. Though the dead floral and faunal tissues constitute the bulk of the food ingested by the earthworms; living microorganisms, fungi, microfauna and mesofauna are also ingested as part of their food. All these faunal representatives along with a diverse flora contribute to soil fertility.

Description

Earthworms are one of the most ancient groups of terrestrial animals reported from precambrian sediments, some 650-570 millions years old. Earthworms contribute at large to the biomass of soil invertebrates, particularly in the temperate and the tropical regions of the world. Their role in turning over of the soil drew the attention of Aristotle who called them "intestines of the earth". Charles Darwin emphasized the role of earthworms in the breakdown of dead plant and animal material in soil and forest litter, and in the maintenance of soil structure, aeration and fertility. Though Darwin's conclusions led to a great upsurge of interest in earthworms from the late nineteenth century, yet the importance of earthworms in agricultural soils is still open to question even 160 years since Darwin published his first paper on the effect of earthworm activity on soils.

Distribution

Earthworms prefer a moist habitat which is reasonably well aerated. They are frequently found in medium textured upland soils where the moisture retention capacity is high, rather than in droughty sands or poorly drained low lands. Soil type and other edaphic factors play a vital role in the distribution of earthworms. The availability of organic matter also greatly influences the earthworm distribution.

Trophic Classification of Earthworms

Earthworms are generally classified into detritivores and geophages based on their feeding habits. Detritivores feed at or near the soil surface, mainly on plant litter or dead roots and other plant debris in the organic matter-rich surface soil horizon, or on mammalian dung. These worms are generally called as humus formers. *Perionyx excavatus, Eisenia foetida, Eudrilus eugeniae, Lumbricus rubellus, Lampito mauritii, Octochaetona serrata, Octochaetona surensis* and *Lumbricus terrestris* are a few examples of detritivorous earthworms. Geophages ingest large quantities of organically rich soil feeding deeper beneath the surface. These are generally called humus feeders. *Octochaetona thurstoni* and *Pontoscolex corethrurus* are some of the common examples.

Classification Based on Ecological Strategies

Earthworms are also classified based on ecological strategies into epigeics, anecics and endogeics.

The epigeics are phytophagous and are efficient agents of comminution and fragmentation of leaf litter. They generally have no effect on the soil structure as they cannot burrow into the soil. The anecics are geophytophagous. They feed on leaf litter mixed with soil of the upper horizons. They may also produce surface casts depending on soil compaction. Endogeic earthworms are geophagous, living within the soil deriving nutrition from the organically rich soil they ingest.

Contribution of Earthworms to Soil Fertility

The concept that earthworms aid in soil fertility had been perceived two centuries ago in 1770 by Gilbert White of Selbourne. Earthworms have beneficial effects on soils, increasing the yield of crops as it has repeatedly been proved and confirmed that earthworms aid soil fertility and enhance plant production.

The endogeic and anecic earthworms associate inside their burrows with free living soil bacteria. It has been well authenticated that the ingested soil and the intestinal mucus of earthworms stimulate microbial activity. An organised creation of structures and burrows, predominantly the vertical burrows by the anecic earthworms and the horizontal burrows by the endogeics, modify the accumulation and circulation of water and gases in soils, which further influence the decomposition of soil organic.

The choice of an environment with organic matter by earthworms leads to the subsequent deposition of worm casts, which again are richer in exchangeable calcium, potassium and total organic matter.

Contribution of Earthworms to Soil Quality

Soil aggregates offer quality to the soil as these aggregates determine the retention and movement of water, diffusion of gases, growth and development of roots in the soil and also provide large surface areas to which Plant nutrients adhere. The capacity of the soil to hold such nutrients is an indication of the potential fertility of the soil.

Enrichment of soil fauna is also partly due to the desired Carbon and Nitrogen (C:N) availability in soils. Earthworms consume very large amounts of litter, and the amount they turn over seems to be more dependent on the total amount of suitable organic matter available than on other factors, and that if the physical soil conditions are suitable, the number of worms usually increase until food becomes a limiting factor. The C:N ratio of freshly fallen litter is high (>20:1) and during the process of litter breakdown and decomposition this ratio is progressively brought down, especially through feeding by earthworms, to levels when nitrogen can directly be taken up by plants.

The concept that earthworms aid soil fertility is now well established and many attempts have been made to ameliorate poor soils using earthworms to improve soil structure as is now being done by IRSBB at Shivri for the UPLDC, Lucknow. This also seems particularly promising in reclaiming flooded areas that are subsequently drained and put into cultivation. And in newly established areas of artesian irrigation apart from the reclamation of subsoils and sandy soils.

Earthworms: Physical Effects on Soils

Earthworm activity influences soil structure by breaking down of organic matter, intimate mixing up of these fractions, ejection of casts that are rich in plant nutrients, and bringing subsoil to the surface. During these processes, thorough mixing of soil, formation of water-stable aggregates, improvement in soil aeration and its water-holding capacity takes place. Earthworms moreover breakdown mineral particles into smaller units by comminution.

Surface or litter dwelling species (epigeics) do not have burrows and it is the anecics and endogeics that make burrows in the soils. The burrowing activity is generally restricted to the top 30 to 40 cm layers of soil, but may be extended to deeper layers due to the scarcity of food or soil moisture. Endogeic species of earthworms which generally make horizontal burrows deposit their casts inside their burrows, while the anecics which predominantly are responsible for

making vertical burrows cast liberally on the surface soil especially in compact soils. Rate of surface cast production is dependent on soil pH, temperature, organic matter and soil type. Of these, the casts deposited beneath the soil surface contribute to pedogenesis, while those deposited on the surface play a significant role in soil profile development. It is unlikely that physical comminution of soil by earthworms will have much significance taking into account the brevity of time spent by soil in the gizzard of the earthworm.

Earthworm casts form soil aggregates, the casts being stabilized after they are excreted, by gums that result from microbial digestion of their organic components or by the binding effect of fungal hyphae.

Earthworms improve soil porosity and soils with earthworms show an increase in soil-air volume from 8 to 30%. These characteristics relate earthworms to water infiltration and the water holding capacity of soils. Higher population of earthworms materially alter soil aeration, drainage and water absorption: and under certain circumstances limit soil erosion by reducing run-off. Instances of earthworm activity increasing waterflow rates through the soil have been reported. Anecic species like *L. terrestris* and also endogeic species like *Apporrectodea caliginosa* and *A. rosea* comprise highly effective water conducting channels when the soil is saturated or when water is administered in large quantities at the surface.

Earthworms: Chemical Effects on Soils

Earthworms affect the chemical composition of soils thereby interacting with the distribution of plant nutrients and their transport by consuming large quantities of surface litter and organic material. In general, earthworms are responsible for transporting this material to the subsurface layers of the soil and during this process much of the organic material is ingested, macerated and excreted. Earthworm casts usually have a higher pH and more total and nitrate nitrogen, organic matter, total and exchangeable magnesium, available phosphorus, base capacity and moisture equivalent. Earthworms also contribute several nutrients in the form of nitrogenous wastes.

The nature and content of the organic matter is an important characteristic of soils. Earthworms prefer soils rich in organic matter or preferably mull soils. The best known example for fondness of organic matter among earthworms is *Eisenia foetida* commonly found in dung heaps and heaps of compost which has made this species a potential agent for waste management. *Perionyx excavatus* and *Eudrilus eugeniae* also exhibit fondness for organic matter. A combination of *Perionyx excavatus* and *Lampito mauritii* are employed in organic solid waste management by IRSBB.

Earthworm Casts

Comparison of vermicasts with the surrounding soils have invariably indicated that casts have a higher base-exchange capacity and are generally richer in total organic matter, total exchangeable bases, available phosphorus, exchangeable potassium and manganese, and total and exchangeable calcium. Though the number of *Azotobacter* and VAM may decrease during passage through the earthworm gut, they considerably increase outside the gut in wormcasts. Other factors may also include the hormone like effects of microbial by-products excreted with the casts.

The most important effect of earthworms may be the stimulation of microbial activity that occurs in casts. This enhances the transformation of soluble nitrogen into microbial protein, preventing their loss by leaching to the lower horizons of the soil. 40% of the total aerobic nitrogen fixers, 13% of the anaerobic nitrogen fixers and 16% of the denitrifiers are in the burrows created by earthworms with the maximum population being within 20-40 cms of the soil. The C:N ratios of casts are however a little higher than that of the surrounding soil with the quantity of carbon and nitrogen excreted in the casts sometimes being very large.

Nitrogenous products of earthworm metabolism are returned to the soil through casts, urine, mucoproteins and dead earthworm tissue. Nitrogen input into soils from dead earthworm tissue alone may be equivalent to 6 to 7 gm^{-2} yr^{-1} and that from excretion of urine and secretion of mucus to 10 gm^{-2} yr^{-1}. Other sources of nitrogen to the soils include decaying roots, excreta from invertebrate and vertebrate fauna, dead plant and animal material, and nitrogen fixation by microbes.

Metabolites in Earthworm Casts and Plant Growth

The reasons for the effect of earthworms on plant growth may be several, apart from the presence of macro and micro nutrients in vermicasts in considerable quantities. There are reports that certain metabolites produced by earthworms may be responsible for stimulating plant growth. It is considered that earthworms release into the soil certain vitamins and similar substances which may be the B group vitamins or some provitamin D or free amino acids. The amount of vitamin Bl2 is generally known to increase two-fold within an year or two after the introduction of worms. Though the NPK value of the vermicast is always lower than any standard chemical fertilizer, several experiments have proved that wormcasts can promote lush growth of plants which probably may be due to plant growth promoters like cytokinins and auxins present in the casts.

Earthworms: Their Effect on Plant Growth

There is ample evidence to prove that earthworms act on litter and that absence of earthworms is characterised by the presence of litter mats on soil surface. Earthworm-inoculated areas are reported to be warmer at night and cooler during the day than the surrounding earthworm-free areas. Soil fertility results from the maintenance of soil conditions, such that, decomposition processes operate at a level adequate to release plant nutrients from litter at a rate that will sustain optimum growth. The two processes, the inherent mineralogical fertility, which owes its source to the parent material of soil, and the biological fertility, which relates to the decomposition of organic material, proceed simultaneously in soils and among the agents for biological fertility, are the soil organisms, and among soil organisms which contribute to the biological fertility of soils, earthworms are the most important.

Effect of Adverse Conditions on Earthworms

Due to climatic changes, soil surfaces may become either too hot or too cold or too dry. Earthworms resist these adverse conditions by either migrating to deeper soil or by becoming comparatively inactive: the latter condition being broadly classified as aestivation, which includes the quiescent stage as for *A. chlorotica*, *A. caliginosa* and *A. rosea* and diapause stage which may be facultative as for *Diplocardia egglestoni*, *O. serrata* and *O. surensis* or obligatory as for *A. longa* and *A. nocturna*.

Diapause in earthworms is reported to begin with the stoppage of feeding, emptying of gut, and constructing a round or oval cell lined with mucus. They then roll into a tight ball, in this process the body reportedly forming one or two knots with the two ends of the worm tucked into the centre of the ball, this process reduces water loss to a minimum in an otherwise adverse condition for *O. serrata* and *O. surensis*.

Charles Darwin stated that "earthworms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds". Very high positive correlations have been reported between the availability of earthworms in soils and plant growth. The total dry matter production of grass, wheat and clover is reported to increase several fold in the presence of earthworms. Experiments have supported the effect of earthworm treatment on the survival and growth of maize plants, paddy and sugar. The quality of vegetables and sugar cane grown in earthworm inoculated soils has been reported to be superior.

Adverse Effects

Earthworms are also reported to damage crops by either seizing leaves of live plants and pulling them down or by uprooting delicate seedlings. Earthworms have also been incriminated in transmitting many parasites and diseases of plants and animals.

Conclusion

By virtue of their behavioural properties, earthworms improve soil structure, soil fertility, promote soil aggregation, encourage favourable soil reactions and enrich the nutrient status of soils thereby promoting plant growth and improving the quality of the plant produce.

Section III

Seeds, Genetic Resources and Food Security

Section editor: Vandana Shiva

This section deals almost entirely with the issues of biodiversity and the colonization of the seed by transnational corporations.

The first article begins by explaining why there is a biodiversity crisis. The reasons set out are not only ecological but political and economic as well. It then examines aspects of biodiversity conservation at site (*in situ*) and conservation in gene banks (*ex situ*).

The second section comprises a basic manual for those interested in *in situ* conservation of biodiversity. The manual in fact deals point by point with several practical aspects involved in the collection and conservation of seeds. It also examines traditional seed storage processes for conservation of local varieties. The section ends with a data collection form which will be useful for those involved in seed collection for conservation.

The second essay, 'Colonisation of the Seed' deals with how recent changes in agricultural production have focussed almost exclusively on the seed and why. It shows how present day agricultural research continues to function as a means of eliminating barriers to the penetration of agriculture by capital. The thrust of the essay is that the seed has to be transformed materially if a market for profits has to be created. It shows how the resulting variety of seeds—which are now no longer grain but commodities—pose a singular threat to food security and why this should be resisted with vehemence. The article also shows how modern research into plant improvement is based on the destruction of the very biodiversity which it uses as raw material. Only when diversity is made the logic of production can it be conserved? Present methods of production based on monoculture will continue to aggravate the biodiversity crisis.

The final article by Bernard Declercq lists out very practical ways of meeting the challenges of food security at the domestic level through establishing circle-shaped kitchen gardens.

Biodiversity: the Principal Issues

By Vandana Shiva

"Today's gardeners cannot possibly comprehend the amount of history contained in their seeds, both what has come before and what may potentially come after their brief involvement."

Suzanne Ashworth, in *Saving the Seed,* 1992, pg. 19

The entire variety of plants, animals and other living organisms on the Earth constitute the biodiversity of this planet. The aggregate of all cultivated crops encompasses agricultural biodiversity. The tropical countries, situated around the equator, are home to most of the biodiversity of the planet. Early in the twentieth century, Nikolai Ivanovich Vavilov, an outstanding biologist, geneticist and plant explorer, mapped out the major centres of agricultural biodiversity. [*See map on page 186*]

We consider biodiversity as not merely the genetic components of diverse species but the interrelationships among the plants, animals, micro-organisms, soil and water. The diverse climatic and ecological zones of India provide a congenial setting for the evolution of a wide range of ecosystems. From the tropical Western Ghats to the temperate Himalayas, and from the fertile coastal regions to the cold deserts of Ladakh, India supports a strikingly rich floral and faunal diversity (ecosystem diversity). Agricultural biodiversity consists not only of crops such as wheat, rice, rajma, bananas (species diversity), but also of the immense variation within each of these crops *(varietal diversity).*

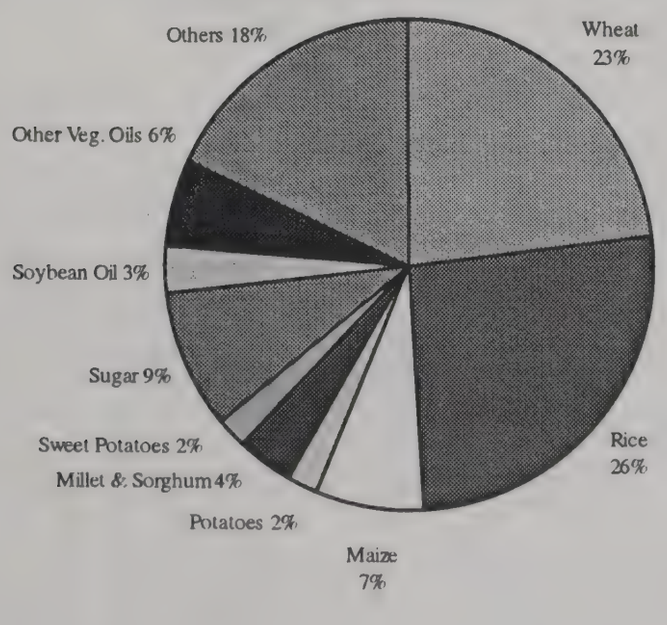


Fig.1: Most important crops for food energy supply

The Great Genetic Treasure Map

This map shows the twelve areas around the world—called centers of diversity—that hold the greatest concentration of germplasm important to modern agriculture and world food production. While evidence indicates that some of the crops listed originated in their respective centers, no one knows for sure exactly where most crops first got started.

New World Centres

1. Mexico-Guatemala

Amaranth
Beans
Corn
Cacao
Cashew
Cotton
Guava
Papaya
Red pepper
Squash
Sweet potato
Tobacco
Tomato

2. Peru-Ecuador-Bolivia

Beans
Cacao
Corn
Cotton
Guava
Papaya
Red pepper
Potato
Quinine
Quinoa
Squash
Tobacco
Tomato

3. Southern Chile

Potato
Chilean strawberry

4. Brazil-Paraguay

Brazil nut
Cacao
Cashew
Cassava
Para rubber
Peanut
Pineapple

5. United States

Blueberry
Cranberry
Jerusalem artichoke
Pecan
Sunflower

(See map)

Old World Centres

6. Ethiopia

Banana
Barley
Castor bean
Coffee
Flax
Okra
Onion
Sesame
Sorghum
Wheat

7. Central Asiatic

Almond
Apple
Apricot
Broad bean
Cantaloupe
Carrot
Chick pea
Cotton
Flax
Grape
Hemp
Lentil
Mustard
Onion
Pea
Pear
Sesame
Sorghum
Wheat

8. Mediterranean

Asparagus
Beet
Cabbage
Carob
Chicory
Hops
Lettuce
Oat
Olive
Parsnip
Rhubarb
Wheat

9. Indo-Burma

Amaranth
Betel nut
Betel pepper
Chick pea
Cotton
Cowpea
Eggplant
Hemp
Jute
Lemon
Mango
Millet
Orange
Black pepper
Rice
Sugar cane
Taro
Yam

10. Asia Minor

Alfalfa
Almond
Apricot
Barley
Beet
Cabbage
Cherry
Date palm
Carrot
Fig
Flax
Grape
Lentil
Oat
Onion
Opium poppy
Pea
Pear
Pistachio
Pomegranate
Rye
Wheat

11. Siam, Malaya, Java

Banana
Betel palm
Breadfruit
Coconut
Ginger
Grapefruit
Sugarcane
Yam

12. China

Adzuki bean
Apricot
Buckwheat
Chinese cabbage
Cowpea
Sorghum
Millet
Oat
Orange
Peach
Radish
Rhubarb
Soybean
Sugarcane
Tea

"They [extinctions] are running at a thousand times the natural rate, threatening the very balance of evolution itself. About twenty-seven thousand species a year are already being lost, or seventy-four a day, three an hour. Within the next fifty years, experts predict that we will lose at least a quarter of the 250,000 known plants." (Kenny Ausubel/*Seeds of Change*, 1994, pg. 20)

Erosion of Diversity

The agricultural crops of today form a minor fraction of the diverse foods that filled the baskets of early agriculturists and food gatherers. In the course of human history, approximately 7000 plants have been cultivated for food; today a meagre 30 crops provide 95% of humanity's dietary energy. In this context, it is interesting to note that, according to the Food and Agricultural Organization (FAO), around 30,000 plant species have so far been used as food by humans.

The FAO report on the State of the World's Plant Genetic Resource for Food and Agriculture (SWPGRFA) published in 1996 warns of a drastic decline in the diversity of crop plants all over the world. Examples of this decline include:

- India: India once had 30,000 varieties of rice; today, 75% of rice production comes from 10 varieties. (*Return to Good Earth*, 1990]
- China: In 1949 China had 10,000 wheat varieties in use; by the 1970s, only 1,000 were still in use.
- United States: Approximately 97% of food plant varieties available to United States farmers in the 1940's no longer exist. (*FAO*, 1996)

"In the great laboratory of Asia, Europe, and Africa, unguided barley breeding has been going on for thousands of years...Spikes [of barley] from Egyptian ruins can often be matched with those still growing in the basins along the Nile...The progenies of these fields with all their surviving varieties constitute the world's priceless reservoir of germ plasm...When new barleys replace those grown by the farmers of Ethiopia or Tibet, the world will have lost something irreplaceable." H.V. Harlan and M.L. Martini U.S. Department of Agriculture *1936 Yearbook of Agriculture* as quoted in Shattering, Fowler & Mooney, 1990 pg. 61

"The chief contemporary cause of the loss of genetic diversity has been the spread of modern commercial agriculture. The largely unintended consequence of the introduction of new varieties of crops has been the replacement and loss of traditional, highly variable, farmers' varieties." (*FAO*, 1996)

Ecological Reasons for the Decline of Diversity

As acknowledged by the FAO, the single most important reason for the steady decline in farm biodiversity all over the world is the introduction of modern hybrids which have wide adaptability, making it possible for them to be grown over large tracts of land, displacing indigenous crops which had previously been cultivated. Additional reasons for the decline have been changing agricultural patterns, subsidies to irrigated chemical farming and massive outbreaks of new pests, diseases and weeds. The situation was further worsened by the widespread existence of environmental degradation, population pressure, civil wars and unsustainable agricultural and natural resource policies. The shift to profit-driven agriculture in India saw the elimination of many of India's traditional crops and their varieties. Extensive deforestation and loss of common lands due to "developmental activities" has resulted in a tremendous loss of biodiversity and its sustainable utilisation, thus undermining the very basis of the livelihoods of indigenous peoples and subsistence farmers.

Biotechnology and genetic engineering pose new threats to biodiversity. Transgenic crops and genetically modified organisms have been found to transfer as much as two to four percent of their altered genes to their wild and weedy relatives, which in turn can make them "super weeds". These weeds can upset the delicate natural balance of ecosystems and result in the extinction of surrounding plant and/or animal species. Also, crop plants with herbicidal tolerance genetically engineered into them, could encourage farmers to increase the use of toxic herbicides. This, too, is likely to result in the extinction of wild plant species in the vicinity of agricultural farms.

Political and Economic Reasons for the Decline in Biodiversity

New threats to agricultural biodiversity have also originated from the new economic policies under the liberalization and globalization of trade. The policies the World Trade Organization (WTO) and the General Agreement on Trade and Tariffs (GATT) oblige member countries to open their markets to multinational companies such as Cargill and Monsanto, who already control much of the world's grain and seed trade. The ability of such companies to cheaply import food grains can jeopardize the Indian farmer's bargaining power and change the agricultural cropping patterns from grain to commercial crops, and from diversity to monocultures. This will accelerate the loss of biodiversity as well as further alienate farmers from their lands and reduce them to pawns at the mercy of the fluctuating global market.

Another major cause for the erosion of the planet's biodiversity is the growing practice of patenting of life forms. Trade Related Intellectual Property Rights (TRIPs) and Plant Breeders Rights (PBRs) allow monopoly control over biodiversity by making it legal to hold patents on life forms. Several crop plants (farmers' varieties and varieties improved upon by new technologies) are being screened by multinational corporations for potential patents. Patents give the owner of the seed the exclusive right to multiply, save, develop further varieties and sell seeds, effectively barring the farmer from these traditional farming activities, including the exchange or seeds. Thus, this ability of a company to claim monopoly power over a seed or crop eliminates the farmer's ability to exercise the mechanisms by which agricultural biodiversity has been preserved. Broad patents, such as the one awarded to Agracetus (a U.S. Corporation, recently taken over by Monsanto) for a soybean, will actually stifle, rather than stimulate innovation in crop breeding. In the words of Dr. Geoffrey Hawtin, Director General of the International Plant Genetic Resources Institute,

"The granting of patents covering all genetically engineered varieties of a species, irrespective of the genes concerned or how they were transferred, puts in the hands of a single inventor the possibility to control what we grow on our farms and in our gardens. At a stroke of a pen, the research of countless farmers and scientists has potentially been negated in a single, legal act of economic hijack."

In addition, these unfair exclusive rights over biodiversity and farmers' varieties disregard farmers' contribution for thousands of years in nurturing and maintaining the seed's biodiversity.

Conservation of Biodiversity

Biodiversity conservation strategies can be done *ex situ* or *in situ*.

Ex Situ Conservation

"*Ex situ*" literally means "out of site," that is, not in a plant's original or natural environment. This has been the predominant mode of conservation for the past 20 years. *Ex situ* collections include botanical gardens, genebanks, field genebanks and *in vitro* collections. Seeds of species that can be dried to low moisture content (5% or less) without damage (orthodox seeds) are stored in genebanks. The field genebanks and in vitro methods are used mainly for vegetatively propagated plants and species whose seeds are killed when their moisture content is reduced below a certain limit (recalcitrant seeds). Approximately 6.1 million accessions are stored worldwide in *ex situ* germplasm collections of which only 527,000 accessions are

stored in field genebanks and fewer than 37,600 accessions are being conserved *in vitro*. Seed storage is thus the predominant form of plant genetic resources conservation, accounting for about 90% of the total accessions held *ex situ*.

Genebanks

Genebanks ideally aim to collect random samples of each accession representing maximum variability ill a given population. The main objective of the genebank is to provide ideal storage conditions for the germplasm (seeds and vegetative material like rhizomes, stem cuttings, tubers etc.) so that the life period (mean viability period) is extended by preserving them in a state of physiological dormancy.

The 3 types of collections maintained by genebanks are:

1. *Base collection* (for long term storage): The seeds are stored at a low seed moisture (4-6%) and a temperature of -18°C or less.

2. *Active collection* (medium term storage): where the material is stored up to twenty years with moisture levels of 7-9% at 0°C or above. Such collections are used for initial multiplication, regeneration, distribution, evaluation and characterization.

3. *Working collection*—This sort of collection is not considered as part of the genetic resources conservation system in a genebank. Material kept in working collections are generally held in short term storage and used by plant breeders for comprehensive evaluation and testing, selection and hybridisation.

Field Genebanks and *In vitro* Collections

Plant species that are vegetatively propagated, that have long life cycles or produce short-lived (recalcitrant) seed are commonly maintained in field genebanks. Collections of plants from aquatic habitats, tubers, rhizomes and large-seeded woody perennials like mango, jackfruit, coconut, etc. are thus maintained in field/orchards or plantations.

In vitro storage ("*in vitro*"—means, in glass) is now being developed as an alternative or complementary method of storage of vegetatively propagated plants. Tissue cultures of these plants are stored *in-vitro* under:

i) Minimal growth conditions—for short to medium term storage of tissue samples

ii) Cryopreservation-storage of tissue in liquid Nitrogen (–196° C) for long term storage.

The advantage of the *in vitro* conservation method is that cultures can be rapidly multiplied when required.

Botanical Gardens

Botanical gardens maintain living collections of plant genetic resources of medicinal, ornamental, as well as food and agricultural importance. They have played a major role in introduction of new crop plants in many countries of the world. Sometimes they also have seed banks or *in vitro* collections. Many are involved in taxonomical and other types of research. They also perform a useful educational role. There are 1500 botanical gardens in the world, and 250 of them have active conservation programmes.

Inadequacies of the present *ex situ* genebank system

Exclusive dependence on genebanks for the conservation of crop plant genetic resources has proved to be vulnerable and inadequate for the following reasons:

1. Taxonomic and agronomic characterization of accessions in genebanks provide essential information for gene bank management. Some of this data can also be useful to plant breeders. Much of the world's germplasm, stored in genebanks is insufficiently and poorly documented. The total number of germplasm accessions held by the world's genebanks is estimated to be 6.1 million. According to a study made in 1984, 80% of accessions in the world's collections are not characterised and only 1% has been extensively evaluated. Another study in 1987 indicated that 80-95% of the world's germplasm collection lacks characterization or evaluation data (*FAO, 1996*). Incomplete documentation and evaluation of the germplasm in the genebanks is a major hindrance in their utilization. According to the WIEWS (FAO World Information and Early Warning System) database, incomplete documentation of germplasm has resulted in its unnecessary duplication and triplication in other places, which occupies precious storage space in genebanks.

2. Literally frozen in time, the seeds in a genebank are torn away from the process of evolution in the natural environment. Environmental destruction is rapidly changing the global climate and agroecosystems. Since seeds/germplasm frozen in the genebanks are not co-evolving with the changing environment, there is a strong chance that they may not adapt favourably to the field conditions at a later point in time.

3. *Ex-situ* genebanks are totally dependent on advanced technology which is capital and energy intensive, often beyond the capacity of many third world countries. A large number of genebanks in the developing countries were set up with financial aid from Western countries. Some of these genebanks have now closed or are in a state of rapid deterioration due to the lack of sustained financial support.

World's Top 10 Seed Corporations		
Company	**Est.1995 Sale US$ Millions**	**Comment**
Pioneer Hi-Bred Intl. (USA)	$1,500	
Novarits (Switzerland)	$900	Formerly Ciba Geigy and Sandoz
Limagrian (France)	$525	French cooperative
Seminis (Mexico)	$500	owned by Empresas La Moderna (Mexico) & George J. Ball (USA)
Zeneca/Van der Have (The Netherlands)		pending merger
Takii (Japan)	$450	veg. /flower /maize /turfgrass
Dekalb Plant Genetics (USA)	$320	About 40% owned by Monsanto
KWS (Germany)		
Sakata (Japan)	$300	vegetable /flower /turfgrass
Cargill (USA)	$250	Privately held
Source: *RAFI COMMUNIQUE*, Sept. 1996, pg.3.		

Some of the main constraints cited by countries in their reports to the FAO are:

1, Equipment problems particularly in seed cleaning equipment, humidity control equipment and cooling units.

2. Insecurity of electrical supply and the need for backup generators.

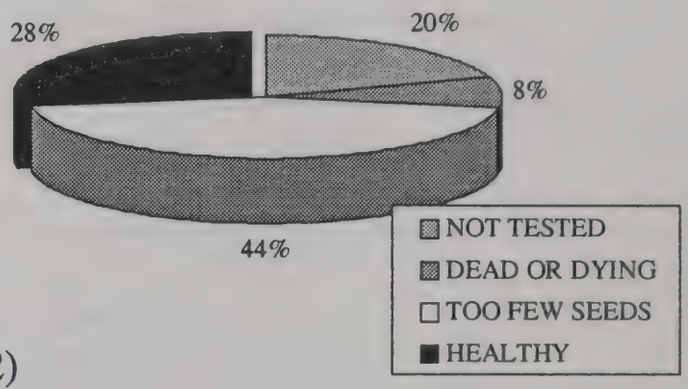
3. Difficulties in seed drying, especially in the humid regions of Africa, Asia and Latin America.

4. Even under optimal *ex situ* storage conditions, there is a certain decline in seed viability, which necessitates their regeneration to replenish the stocks. FAO estimates that as many as one million accessions may now be in need of regeneration. The major constraints for lack of regeneration pointed out by most countries are, poor or no long term storage, funding, facility and staffing constraints, problems with cross pollinating species, etc.

FORT COLLINS: BANK OR MORGUE?

The largest gene bank in the world is the U.S. National Seed Storage laboratory (NSSL) in Fort Collins, which stores 2,32,210 seed samples. Of these only 64,036 or a meagre 28% have been found to be healthy. Almost three quarters of the collection have not been tested in at least 5 years, contain too few seeds to risk testing or do not meet the U.S. Standards for viable seeds. Major Goodman, a crop geneticist at the University of North Carolina has said: "I would maintain that these banks are seed morgues. What goes in, isn't going to come alive."

OF ALL SAMPLES, ONLY 28% FOUND HEALTHY



(Fig. 2)

5. For safety reasons, duplicates of the germplasm held by national genebanks are deposited in the relevant CGIAR (Consultative Group on International Agricultural Research) centres or other genebanks. But, in their reports to the FAO, many countries note that they don't have duplicates for the accessions they hold.

6. Seeds that are stored in genebanks are technically available to farmers, public sector research institutions as well as to the private sector. In practice, individual farmers do not have the same access to these banks, most of which are in developed countries and they lack the required time and resources to get the seed. At the same time, private seed companies with their vast resources and branches in various parts of the world can easily get the seed, and then patent any modification. Thus, while the farmer "donates" the germplasm freely, the same is sold back to him/her as the property of the company that has patented it.

In Situ Conservation

"...The best place for seed is in the ground ..."
Michel and Jude Fanton/*Saving the Seed,* 1993

As is evident, *ex situ* conservation has several constraints. Therefore it must be complemented by alternative conservation strategies to ensure that our rich agricultural diversity continues to offer us ecological and economic security. In contrast to *ex situ* conservation, *in situ* conservation maintains plant populations in their natural or agricultural habitat, allowing the evolutionary processes which shape the genetic diversity and adaptability of plant population to continue unhindered. In on-farm conservation, farmers' varieties continue to evolve, influenced by natural selection as well as the selection pressures imposed by the farmer, and thereby enabling continuous crop adaptation and improvement.

In the conventional *ex situ* genebank model, the farmer is merely the supplier of genetic material to be kept under high-technology conditions for future use by breeders and seed companies. He/she is distanced from his/her role as plant breeder. The only other role for the farmer envisaged within this system is as a consumer of the improved seed. In contrast to this, *in situ* conservation can enhance the farm biodiversity utilization at the local level and contribute to agricultural development and food security.

Ideally, *in situ* conservation efforts should include:

- Conservation and sustainable utilization of farmers' traditional crop varieties on farm, and in home gardens.
- Sustainable management of forests, grass lands, human inhabited ecosystems, etc.
- Specific conservation measures for crop wild relatives and wild food plants, particularly in protected areas. [Adapted from *FAO*, 1996].

Farmers as Conservers

In most countries, farmers have been conserving their traditional crop varieties as part of their farming system for centuries. Farmers have selected their varieties to suit the environment in which they are cultivated and to satisfy their particular needs such as flavours and cooking qualities. The fortunate fact that modern agriculture and developmental activities have made few inroads into geographically isolated areas, tribal belts, marginal and rainfed lands has preserved the biodiversity in these areas.

Religion and cultural traditions have also influenced the choice of crops cultivated by farmers and thus preserved their agricultural biodiversity. Major Indian festivals like *Pongal, Onam, Holi, Akshay tritiya* coincide with important agricultural activities like harvest, sowing, etc. In the Chattisgarh region of Madhya Pradesh (which is one of the centers of diversity of the indica variety of rice), *Akti* is an important festival. During this festival, farmers from surrounding areas bring their diverse paddy varieties to the village temple and worship them. Subsequently they are mixed together and shared amongst the farmers. The ritual reinforces the many core principles of biodiversity conservation and asserts that seed is a common, shared resource.

The farming practices of small farmers and farmers in marginal lands have always been diversity-based. The mixed-cropped farming by such farmers in the tropics and sub-tropics are based on planting a wide variety of crops together. Growing diverse crops in one's land ensures a nutritiously diverse diet and food security in times of adverse agroecological conditions. For example, most farmers in Central Himalayas (Garhwal) grow almost all the food they require and are only marginally dependent on the market for food. In the "baranaaja" fields in Garhwal, farmers grow up to twenty different crops together, comprised of cereals (maize), millets (finger millet, sorghum, barnyard millet,) pulses (blackgram), greengram, horse gram, kidney bean, native soyabean) oilseeds (niger, sesame) and pseudocereals (amaranth, buckwheat.)

Farmers as Breeders

Farmers' varieties are the products of domestication and constant development carried out by the farmer through crop breeding practices. Farmers have been experimenting, crossing, selecting and saving seeds for centuries.

The active involvement of farmers in the selection of varieties is evident in the names they have given their crop varieties:

- *Dodda Beru Nellu*—which in Kannada means "long-rooted rice". A rainfed, red-grained paddy which can withstand drought stress. Probably the long roots enable water absorption from deeper soil layers.
- *Dundkiya mandua*—(dundkiya in Garhwali means "closed")

A finger millet variety from Garhwal with closed ear lobes. The farmers believe that the closed ear lobes make it difficult for birds and bears to reach the grains.

- *Amme Adrak*—(Amme, aam in Hindi means mango)

A variety of ginger with mango flavour. Excellent for making pickles.

The International Agricultural Research Centres now recognize the need to involve farmers in breeding programmes for their crop improvement efforts to be successful .The participatory breeding programmes ICRISAT (International Crop Research Institute for Semi Arid Tropics) conducted in dry regions of Rajasthan found that most farmers in Bikaner district preferred to plant native varieties of pearl millet for their better ecological adaptability. These native varieties were early maturing, and thus evaded drought. They were also tall, thin and had many tillers, thus yielded a high amount of good quality fodder.

The conservation of crops on-farm, therefore requires the traditional knowledge and practical skills and continuation of the farmer-induced selection and breeding processes which developed and shaped them.

Farmers as Consumers

80% of seed used for planting in India comes from farmers' seed supply. Only 20% comes from public and private sector seed industry. In the industrialized countries, the farmer's role in conservation and breeding has been destroyed and they have been reduced to consumers of the seed industry. The power of the seed industry has therefore been based on the destruction of farmers' rights. The new seed policy of 1988 has allowed the entry of the multinational seed industry giants such as Cargill, Pioneer, Ciba-Geigy into India.

Why Conserve Biodiversity in Situ?

Ecological Reasons

1. Monocultures of crops with a narrow genetic base are vulnerable to disease and pest attacks of epidemic scale. Diversity is an insurance against pest and disease attack of such magnitude.

2. Farmers' varieties can withstand ecological stresses better than the modern High Yielding Varieties (HYVs), and need only very low external inputs and natural resources. Contrary to this, the HYVs need a steady supply of irrigation, synthetic fertilizers, pesticides, herbicides, fungicides, etc. for their normal growth and crop yield. Therefore, diversity ensures food security in times of adverse ecological conditions.

3. Farmers' varieties and their wild relatives play a vital role in crop breeding to impart resistance and tolerance to diseases and ecological stresses.

4. A highly diverse agroecosystem, using traditional cropping prac-

tices such as mixed-cropping and crop rotation, not only makes more efficient use of natural resources, but also promotes water and nutrient recycling and conservation.

5. The total nutritional value of food obtained per unit area in diversity-based farming systems is much higher than that obtained in chemically-farmed, single crop-based farming systems.

6. Globally, the growing ecological awareness among farmers and the demand for chemical-free food is resulting in a shift towards organic agriculture. The first step towards organic farming is the use of healthy seeds which are not dependent upon chemicals for growth. Having evolved free of chemicals, farmers' varieties are the best choice for organic farming.

Social and Political Reasons for Conservation

1. Single crop-based agriculture increases the vulnerability of poor farmers to starvation. Biologically diverse crops are both an insurance against natural calamities and the whims and fluctuations of the international grain market. The more diverse a farmer's crops, the more likely some crops are to survive adverse conditions, providing the farmer the means of security and survival. This is in stark contrast to cash crops such as tobacco or sugarcane, which can bring high prices when the market is good, but leave the farmer nothing in the way of sustenance, if the market is not favourable.

2. Planting diverse crops ensures a nutritionally complete diet, improving the health of the farming families who depend upon them.

3. Conservation of agricultural biodiversity is an important step towards ensuring food security of a country, as well as political independence. When the genetic base of food crops grown in a country is narrow, the food security of the nation is in danger. Food can then easily be used as a political weapon in the hands of industrialised countries against developing countries.

4. *In situ* conservation and alternative agricultural arrangements also provide politically necessary conditions for the protection of freedom and sovereignty in the context of seed monopolies through Intellectual Property Rights (IPRs).

Role of Consumers in Biodiversity Conservation

Small farmers have been growing a diverse range of crop plants, which not only ensured food security for farmers but also made the diets of consumers nutritious and complete. Growing economic and social pressures are now forcing farmers to give up diverse, nutritious crops and shift to cash crops and monocultures. As a result, the con-

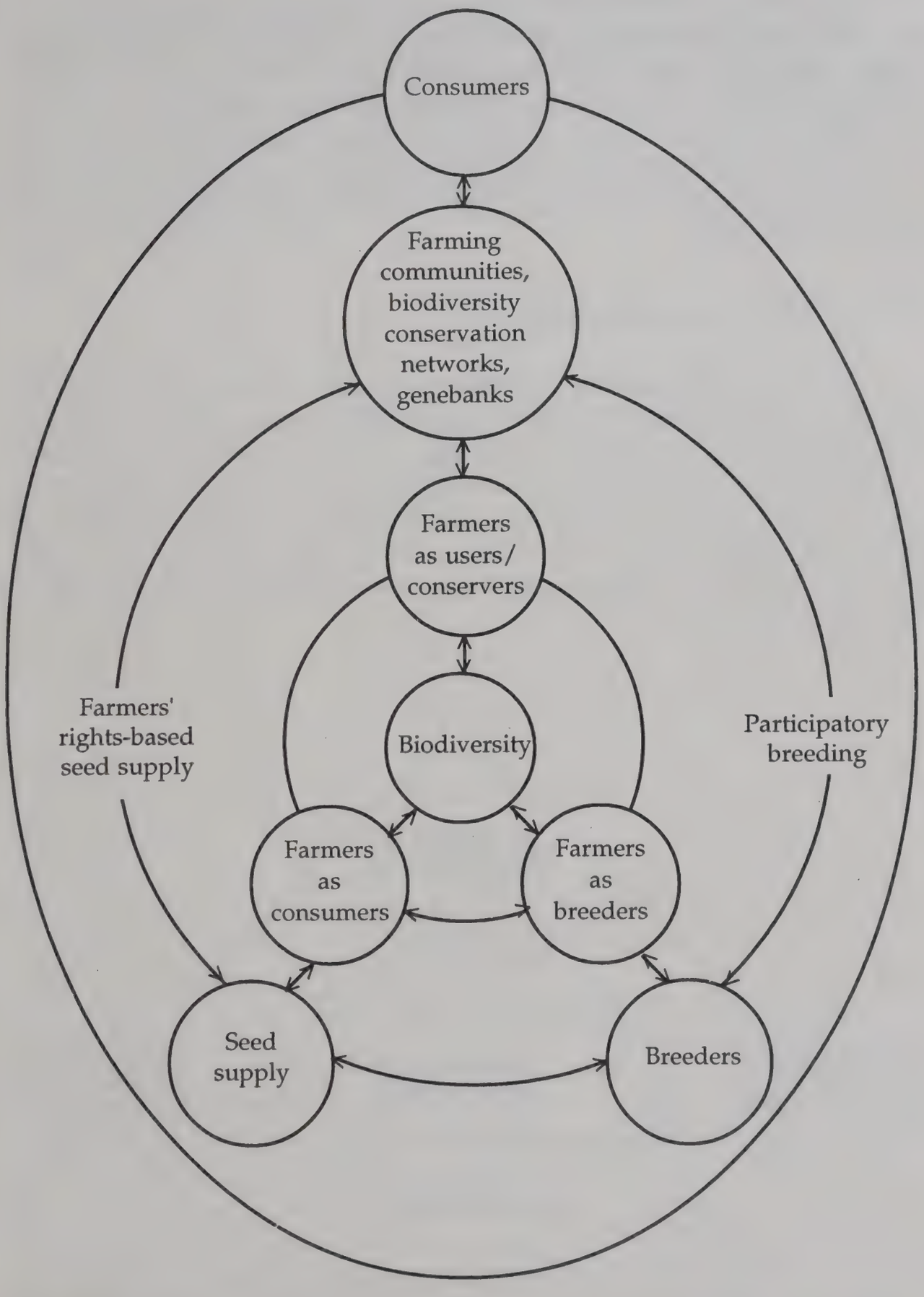


Fig.3: Participatory Conservation and Utilization of Biodiversity (Mutually Supporting Concentric Circles)

sumers are also getting nutritionally impoverished and chemically contaminated foods.

Consumer awareness and demand for healthy, organically grown, nutritious food is growing the world over. Active support from responsible consumers concerned about biodiversity erosion as well as their health could play an important role in continued cultivation and conservation of diverse crops in farmers' fields. Our country needs to have strong direct farmer-consumer links for a healthy nation, economic security of farmers and conservation of our immense agricultural biodiversity.

Two Models of Conservation

There are two models of biodiversity conservation. One model is based on partnership between farmers, NGOs, gene banks and breeders. The other is based on exploitation of farmers' varieties and farmers' knowledge embodied in these varieties, by the seed industry. One model is based on an "ever expanding, never ascending concentric circles" (Gandhi) (Fig. 3), the other is based upon a pyramid in which the top crushes the bottom which supports it (Fig. 4). In the words of Mahatma Gandhi,

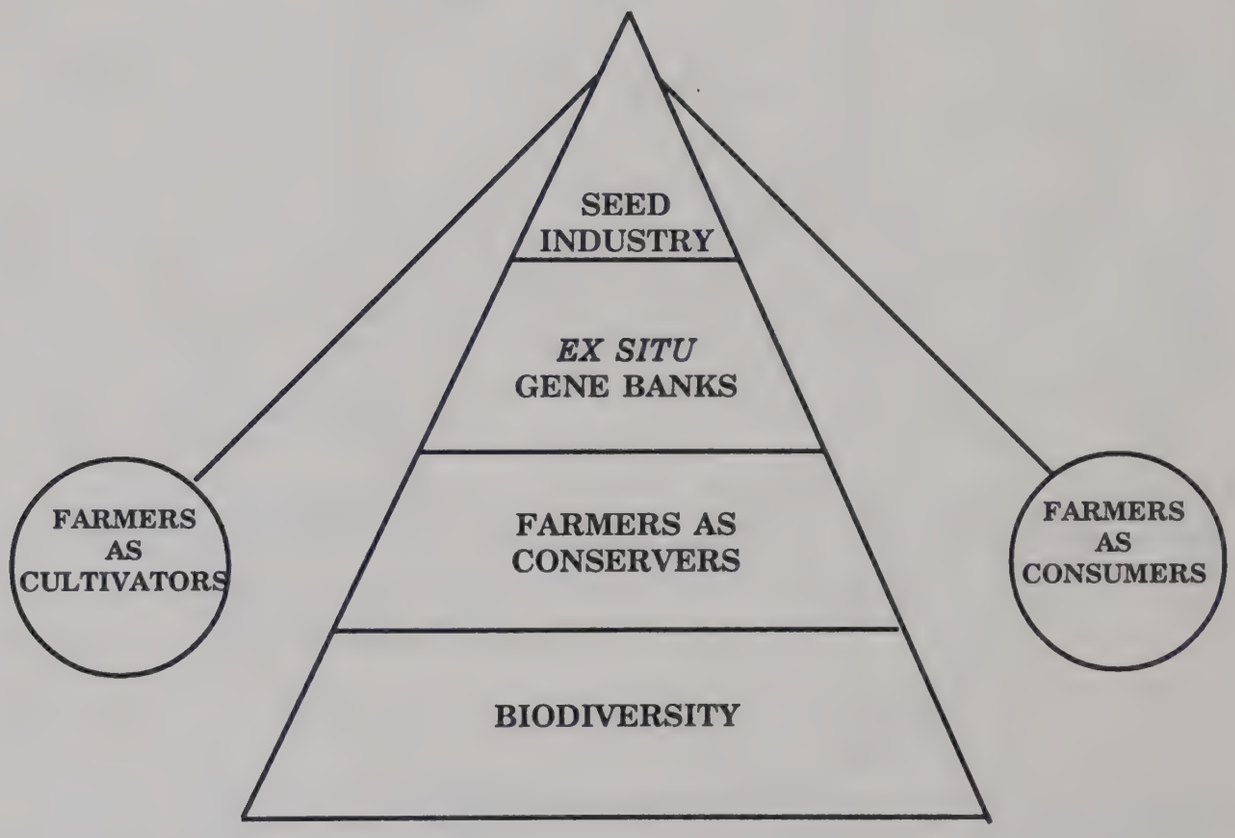


Fig.4: Hierarchical Model of Conservation and Utilization of Biodiversity

"Life will not be a pyramid with the apex sustained by the bottom. But it will be an oceanic circle whose centre will be the individual always ready to perish for the village, the latter ready to perish for the circle of villages, till at last the whole becomes one life composed of individuals, never aggressive in their arrogance, but ever humble, sharing the majesty of the oceanic circle of which they are integral units. Therefore, the outermost circumference will not wield power to crush the inner circle, but will give strength to all within and will derive its own strength from it."

A Beginners's Manual for *In Situ* Conservation of Farm Biodiversity

On farm *in situ* conservation programmes can be organised by local farmers' groups at the community level. They can also be built through conservation programmes of NGOs and research institutions involving farmers at the local, regional and national level.

The various stages involved in organising such an *in situ* conservation programme include:

a) Survey and planning
b) Collection and documentation
c) Seed testing, planting out for multiplication and regeneration.
d) Characterization and evaluation.
e) Selection, harvest and compilation of yield data.
f) Post harvest processing
g) Traditional seed storage and treatment.
h) Community seed banks and seed exchange networks.
i) Market support for *in situ* conservation through consumer networks at local, regional and national levels.

A) Survey and Planning

Exploration and collection of agrobiodiversity needs careful planning to ensure that collection is done in the right places during the appropriate seasons by knowledgeable people.

This requires proper knowledge of the distribution of the diversity in the region. It is also important to know the cropping pattern and crop calendar and the changes that have occurred over the years. Sowing and harvesting time varies, depending on irrigation facilities, lay or the land, climate and altitude. For example, in the same region in Garhwal, rice harvest in the higher rainfed terraces (September) is later than in the lower irrigated valleys (October). In contrast, the rabi harvest of crops like wheat, barley and mustard in the higher terraces is much later (May) than in the lower irrigated valleys (end March-April). In addition, when the activity is being undertaken not by the community itself, but by an outsider or an NGO working with the community, it is important to understand the cultural relationship that communities have with their crops in order not to violate their cultural norms and patterns. It is better to restrict the size of a collection team to two-three members for many practical reasons.

A survey of the whole region is the first step to identify the varieties that are grown, and those which are in the process of becoming extinct. In places where high yielding varieties (HYVs) and hybrids have spread, resulting in changes in the cropping patterns, diversity maybe comparatively less. Special efforts should be made to reach interior villages to identify farmers who continue to grow traditional varieties. Priority in crop diversity exploration should be given to areas which are facing rapid ecological degradation due to deforestation, natural calamities and intensive development.

It is also important to keep in mind the various ecosystems within the region. Sometimes, even within short distances, there may be different micro-ecosystems (lay of land, sunny areas, shady areas, water availability, etc.). Even if the same variety grows in these different micro-ecosytems, each should be counted as a separate accession.

Surveys also help in establishing local contacts with farmers who are growing traditional varieties and involving them in the conservation programme.

B) Collection and Documentation

The objective of the collection trip is to gather maximum diversity within a single crop species or the broad diversity of all the different crops in an area. Prior knowledge about the crop whether it is self-pollinated is helpful in deciding the amount of the sample to be collected. The genetic variability in a self-pollinated crop is low and hence a small sample from a small area is enough to cover most of the variability in the population. In the case of a cross-pollinated crop, the genetic variability is high due to cross pollination and hence the size of the sample size collected should be large, from a large area.

Collection from farmers' fields

The best time to make a collection trip is just before harvest, so that the crop can be seen and assessed in the field. During collection, interaction with farmers could give information on valuable characters like:-

- High yield
- Adaptation to soil and climate
- Palatability, texture, colour, flavour, cooking time, storage etc.
- Disease and pest resistance
- High nutritional value

- Soil enrichment value
- Medicinal and fodder value.

Maximum information about the crop accession/variety should be gathered during the time of collection, while the crop is still in the field.

Before one starts collecting, a visual assessment of the variation of the crop in the farmer's field gives an idea of the variability within the crop. Take the harvest from a single plant every few paces, throughout the field. Then collect seeds of unusual or noteworthy plants (like in the case of cereals and millets, which have bigger ears, high tillering, awns, bristles etc.) But avoid collecting too many unique types. They should form only a small portion of the total sample collected.

While collecting, importance should be given to all aspects of the plant, not the seed or fruit alone. Include some low-bearing plants as well as the best looking and most prolific plants in the sample. This ensures that the sample collected is representative of the maximum variability in the population.

If a sample contains seed-borne or insect infestation, keep the seed separate from the other samples, or else the whole collection could be destroyed. Usually, such problems can be controlled with local practices. In such collections, seeds that can tolerate infection and still bear fruit could be extremely valuable.

Samples of germplasm can be collected from farmers fields, kitchen or orchard gardens, village markets or wild habitats. Kitchen gardens, farmers granaries and weekly village markets and farms are often a rich source of rare varieties of crops.

An organised collecting mission requires:

1. Cloth bags.
2. Plastic Bags, preferably the resaleable type.
3. Knife & Scissors
4. Note books and other stationery, including marker pens.
5. Collection data forms
6. Camera and film rolls (both slide and print films)
7. Hand lenses
8. Altimeter
9. Compass
10. Camping equipment
11. Cooking utensils
12. Torches

13. Sleeping bags
14. Essential medical and first aid kit
15. Transport facility suitable for the terrain explored.

Data obtained through observations and detailed interaction with the farmer on each crop variety collected could be compiled onto a data sheet. A sample data collection sheet could be as given in *Appendix 1.*

C) Seed Testing, Planting Out For Multiplication & Regeneration

For detailed documentation of morphological and agronomic characters and yield data of the crop varieties collected, they have to be further grown out for observations in field conditions. This is best done in the area of introduction itself so that farmers can play an active role in the process of selection of the varieties they favour and their conservation.

Testing for seed viability

It is important to ensure that the seed or planting material used in the field has a high germination potential. The viability or the life of a seed under normal storage conditions in a farmers house varies from species to species. For example, the viability of onion seed is usually a year, whereas seeds of some cucumber varieties are viable for about four years, cowpea upto five years and pumpkin seeds can retain their viability upto ten years if stored in dry conditions. Farmers are very knowledgeable about the life cycle of the crops they grow. So, basic information about the viability of crop seeds, their ideal low cost storage conditions etc., is best obtained from the farmers during the collection trip.

Seed viability tests can be conducted by sowing the seeds in soil or keeping them on a moist paper towel or cloth. Care should be taken that the medium in which the seeds are kept is always moist and in an airy and sunlit region of the room. Seed viability tests conducted in the soil give more accurate information because though seeds may sprout on a moist paper or cloth, they may not have the vigour to push through the soil. 90-95% germination indicates that the viability of the seed is high. If the germination percentage is between 60-80%, the quantity of the seed sown should be increased to compensate for the poor germination. Whenever a seed accession falls below 50% germination, plans should definitely be made to regrow it.

Most of the vegetables, pulses and cereal seeds are soaked in

water (since salt water increases the density of water, saline water could also be used) and only the seeds that sink are used for sowing. Some hard seeds/nuts can be germinated faster if their seed coat is rubbed against a hard surface to make it thinner, cracked slightly, or if they are soaked in hot water. Beds in which ginger and turmeric are sown, if covered with green leaves of Amaltash (*Cassia fistula*) and Toon (*Cedrela toona*) ensures speedy germination and good yields.

In southern India, paddy seeds are soaked overnight in water, the water drained and the seeds are piled in a heap and weighed down with stones. Cowdung, ash and leaves of Castor (*Ricinus communis*), Aak (*Calotropis gigantea*) and *Dodonea viscosa*, etc. (all believed to have insecticidal properties) may be used to cover this heap. After 2 to 4 days, the germination potential is checked and only those seeds with high germination potential are sown.

Traditional methods of seed testing

Women farmers who are the custodians of the seeds, select the seeds from their storage and harvest, and conduct germination tests as a cultural and ritual aspect of farming. In Karnataka this germination test is built into the festival of *ugadi*. Seeds are sown in a flat clay pot or basket with wet sand, or mud from the field itself, and observed till the ninth day. The pot is worshipped, and taken to a nearby water source, where it is floated on the water. If the germination is poor, the farmers do not use these seeds in the field, but borrow or exchange seeds from other farmers.

Seed dormancy

If a viable seed does not germinate in conditions when it should normally germinate (in the presence of adequate moisture, temperature and oxygen), it is said to be dormant.

Treatment to break dormancy

Seeds could be soaked in hot or saline water (for a short period) or subjected to other shock treatments to break the dormancy. Nipping off the shoot tip of the garlic pods before sowing breaks its dormancy and ensures quick germination. We have found this an effective way to break the dormancy of the Himalayan single-cloved garlic—faran—, which otherwise takes almost a month to germinate.

Growing out for Multiplication and Regeneration

It is essential to grow out the collected seeds for replenishing the existing stock of seeds whose viability is decreasing (regeneration). It is also done to multiply seeds of varieties which, if found suitable, could be distributed among farmers who require them.

The seeds or planting material of most cereals, pulses and millets are sown directly into the soil. But seeds of crops like irrigated rice and most vegetables are first sown in a seed bed and then transplanted. Making pellets of seeds by covering them with cowdung or mud before sowing prevents birds from eating them and also ensures quick germination. During planting, optimum distance should be kept between the neighbouring plants so that they grow normally and make proper use of natural resources. Each accession should be separately planted out in distinct patches. This can be done either by keeping an empty space between the patches or by planting another crop on the bunds. The patches could all have labels indicating the accession/variety. A map of the entire multiplication field could be maintained. At the Navdanya conservation and demonstration farm in Dehra Dun, we found that the latter is more practical as it is inexpensive and easy to maintain. Maintaining labels on our farm was difficult because wild boars used to play havoc in our fields at night.

Keeping the purity intact in the case of self-pollinated varieties is easy, as pollen from the same flower fertilises it. Examples of such plants are most of the cereals, tomato, lady's finger, kidney beans, etc. A certain amount of cross-pollination does take place thus bringing about variability in the population.

Cross-pollination (pollen of one flower pollinating another) takes place through wind or with the help of insects. Cross-pollination makes it difficult to keep the purity of the variety intact as it contaminates the true types. Maize, carrots, crops belonging to cabbage family, etc., are all examples of cross pollinated crops.

How to Keep Your Accessions Pure

1. *Grow them apart:* pure seeds can be produced by leaving enough distance between two or more varieties or growing other crops in between to prevent contamination from insect or wind blown pollen.

2. *Isolate them in time:* this is suitable for crops where all the plants flower simultaneously and for a short time and where irrigation facilities allow staggered planting—for example, corn and sunflower. The different varieties of corn and sunflower could be planted at different time intervals to ensure that flowering of each variety takes place at different times.

3. *Bag them:* When only a small amount of seeds of self pollinated crops having absolute purity is required, covering the flowers with a paper bag is adequate. This process is useful in the case of tomatoes and capsicums.

4. *Cage them:* for the total exclusion of insects, crops which are pollinated by insects and which flower over a long time (chillies and brinjal) can be enclosed in cages. Low cost cages can be made from steel or wooden rods stuck into the ground to create a dome shaped structure and covered with wire or nylon mesh. For a row of plants, a common semi-circular tunnel can be made which can be shifted as and when required.

D) Characterisation and Evaluation

Although valuable information about the varieties collected can be obtained from the farmers who gave the seed, there is a constant need to obtain first hand assessment of them by planting them in trial plots, preferably in the area of introduction. This will also help judge the stability of the characters and their performance in a different agroecosystem.

The accession/variety planted out for trials must be characterized and evaluated keeping in mind the farmers' requirements. Hence it is essential to have the active involvement of farmers in doing the evaluation of the crop varieties in the field. This kind of evaluation and documentation is different from what is done by the conventional breeding programmes, which does not involve the participation of farmers. As women farmers do most of the work in the field except ploughing, it is important to seek their opinion in all the characterization work. Characterization and evaluation work has to be done at every stage of growth. Criteria for evaluation can be subdivided into morphological and agronomic characters.

Morphological characters

• *Germination:* The number of days to germination and the rate of germination has to be recorded for every accession/variety planted.

• *Plant height and tillering potential:* These are important characters in evaluating cereals and millets. These characters are highly valued by farmers who own cattle, as tall, high tillering varieties yield more fodder. Normally, crops with high tillering capacity yields more grain as most of the tillers bear an ear. According to a study done by ICRISAT, farmers in Rajasthan preferred varieties of pearl millet with high tillering capacity over the improved varieties they supplied.

• *Other vegetative characters:* Documenting characters like growth habit, leaf colour and shape, stem colour, hairiness, pigmentation,

fruit/ear shape, seed colour, presence of bristles, awns on the ear etc. helps in characterization and identification of the accessions. We, at Navdanya, found that usually women farmers are more knowledgeable about the external appearance and identification of individual accessions/varieties.

• *Onset of flowering and seed setting:* The number of days from sowing to flowering and then to seed setting and harvest needs to be recorded. This helps the farmer in planning his/her agricultural calendar accordingly. It is very important to ensure that there is adequate irrigation during the time of seed setting. This will enable the formation of properly formed seeds.

• *Non-lodging character:* Farmers are hesitant to grow varieties which tend to lodge, as they could result in heavy loses and difficulties during harvest. Therefore, it is very important to note those varieties which resist lodging even during heavy winds.

Agronomic characters

• *Tolerance to drought:* A small sample of all the seeds collected could be planted out separately in a dry portion of the farm and grown unirrigated. The yield obtained could then be compared with those obtained form irrigated plants and the varieties judged for their drought tolerance.

• *Pest and disease tolerance:* Observation of crops in the field during the growing period for disease and pest incidence and their ability to cope with any such attacks will give valuable information on their level of tolerance.

• *Ability to compete with weeds:* Weeds can often be a major hindrance in the proper growth of plants. Field trials could indicate each variety's ability to tolerate the presence of weeds and still yield substantially.

• *Resistance to bird/animal damage:* Presence of bristles, thorns, hairs, and awns in grain ears are characters which deter grain-eating birds. In our interaction with farmers living in villages bordering forest areas where bird and animal attacks are frequent, we have noticed that they prefer awned varieties of rice and wheat to awnless varieties.

• *Maturity period:* Knowledge of the exact days to maturity is essential. Introduction of early maturing varieties in dry regions could be an effective way of evading drought conditions.

• *Frost tolerance:* In Northern India and higher altitudes, crop varieties which can withstand frost damage are likely to do well in the harsh winter conditions. Crop loss during hailstorms and heavy rains

Home-made Growth Regulators

- 10 kg. of manure consisting of 50% cow dung and 50% green leaves and mulch put in bag, is dipped into a barrel containing 200 lts of water. The contents are kept covered for 3 weeks, and stirred everyday for a few minutes to let some air into it. When the liquid is ready and odourless, 200 gm. of jaggery (gur) is added. One week later, when the growth hormone is ready, it is stored in an earthen pot away from direct sunlight.
- 1 litre of cow's urine is diluted with 5 litres of water. A bag of seeds dipped in this mixture and then dried in the shade germinates well when sown.

is less on crop varieties with non-shedding (grains) and non-shattering (legumes) characters.

During collection, it is often not practical to obtain the morphological and agronomic character required to make the data sheets complete. Hence, the data from the field trials should be compiled with the data obtained from the farmer during collection. All the above characters, if obtained give a complete and detailed account of each variety and would be useful for seed exchange and introduction to new regions.

E) Selection, Harvest and Compilation of Yield Data

Selection of planting material

Selection of seed/planting material from the trial plot should be done to retain the desirable qualities of that variety. The size of the fruit/length of the ear and such other obvious characters should not be the only criteria for selection of seeds. The aim of selection should be also to maintain a fair degree of variation within the varieties. Retaining certain optimum amount of variability in open pollinated crops (most of the farmers; varieties) is essential for them to adapt to changes in soil, cultivation methods, latitude, planting time or climate, and to have tolerance/resistance to diseases, pests, drought, etc. Seeds should be selected from plants with fruits that are not big but have consistently yielded, throughout the season, even through spells of bad weather, diseases, and pest attacks. If you are conserving some varieties in your own home garden, to prevent family members from picking the fruit from the plants that you intend to save for seed, they can be marked or tagged. Generally the best time for the collection of seeds is when the dew has dried in the morning.

Selection of good seed is crucial for healthy agricultural practices. A good harvest depends on the quality of the seed. Farmers have developed skilled selection methods for each crop and this knowledge is passed down generations. Given below is a compilation of relevant points that farmers keep in mind during the selection and harvest of seed/planting material. This data is compiled from Navdanya's regional centres and a survey of literature.

1. *Cereals and Millets:* In the case of millets like finger millet, barnyard millet, and foxtail millet, long, heavy ears should be selected and cut separately. For paddy, either the healthy ears should be cut separately or the entire plant should be cut and kept apart from the rest of the harvest. In general, the ears chosen for seed should not be diseased, insect ridden or chaffy, and should be fully ripe. The harvest should be piled and kept for around two days, threshed, and the seeds stored appropriately. In Orissa, farmers ensure that their variety of paddy is pure by husking a few seeds in each panicle to check whether the grains are of the same colour, size and shape.

2. *Pulses:* For legumes whose pods do not snap and scatter the seeds, the pods should be picked from the plants only after they are fully dry. This is to make sure that the seeds are well formed and mature. In the case of legumes whose pods snap, the entire plants are cut just before the pods are dry. The plants are kept in a pile for a few days to mature and then threshed.

3. *Oil seeds:* Some oil seed crops like sesame and the various mustards shatter their seeds when they are fully ripe and are therefore cut just before they ripen. They are then tied in bundles, stacked in a heap for a few days and then threshed to obtain the seeds.

4. *Maize:* Since maize is a cross pollinated crop, ideally cobs from 50-100 plants should be saved for seed to maintain diversity. If too few plants are selected, there will be an irreversible loss of characteristics. For example, multi-coloured corn may lose some colours and some of its insect resistance. Another corn variety may lose its earliness, and yet another, might lose its productivity.

5. *Vegetables:* For cucurbits such as pumpkins, melons and cucumbers, a minimum half a dozen fruits should be kept each season for seed saving. It is advantageous to keep seed of fruits from different vines rather than a single vine. The best stage for collecting pumpkin seeds is a couple of weeks after the fruit ripens, when the seeds have matured. In the case of cucumber and lady's finger, the fruits should be allowed to reach full size and then left for another three weeks to allow the seeds to mature. For vegetables such as tomato and brinjal, the fruits are best picked for seed when they are ripe and turning soft. In addition, for tomatoes, the fruit should be preferably picked

from plants with high leaf density, which gives essential shade to the fruit in the summer heat.

6. *Root crops:* In the case of tubers of potatoes or rhizomes of ginger, the largest, smoothest and most representative specimens should be selected for replanting. In tuber crops like yams and tapioca, the varieties which grow in the upper shallow soil layers are preferred by farmers over those which are deep-seated. The deep-seated varieties are difficult to dig out and often break underground. Some yam varieties of *Colocasia* and *Amorphophallas* have edible stems and leaves besides their tubers and hence are preferred over the ones in which only tubers are edible.

7. *Greens and herbs:* For leafy vegetables like spinach, methi, and coriander, it is better to take seeds from plants with a prolonged leaf stage than ones which send up a seed stalk early in the season.

8. *Spices:*

Black pepper: Farmers in the Uttar-Kannada district of Karnataka are very particular about the vines from which they take stem cuttings for propagating pepper. They usually look for vines which yield good seeds and are resistant to quick-wilt disease. Succulent lateral branches are preferred as planting material.

Cardamom: Ripe, yellow-coloured, bold capsules are selected by farmers for seed.

9. *Coconut:* Since the coconut tree lives long, selection of good seed is very important. Usually for seed selection, taste, oil content, and fleshiness are taken into consideration. The other important points for the selection of mother tree are given below:

i) The tree should be 35 to 45 years of age.

ii) The trees should be strong, have 25-30 leaves, and yield 200-250 coconuts per year.

iii) The husked nut should be big, round and produce a metallic sound when tapped.

Recording Yield Data

Traditional farming systems are based on mixed cropping and rotation of diverse varieties of cereals, millets, pulses, vegetables, tubers, and oil seeds, whereas modern farming systems are largely based on monocultures of genetically uniform crops. The green revolution crop varieties were developed with the aim of increasing just the grain yield, regardless of the other useful products obtainable from the plant. There has been no realistic assessment of the overall yield of diversity-based farming systems. Therefore, a complete assessment of farm productivity, including yield from one crop species

(grain, straw, husk, nitrogen fixing capacity) and from the total biodiversity in the field (like the trees on bunds which yield fodder, fibre, fruits, and firewood) gives a better picture of the full benefits of traditional farming systems.

To make a complete assessment of each rice variety in our conservation farm at Dehra Dun, we calculated the grain and straw yield per unit area. For easy calculation of yield per unit area and to do the comparative assessment of the varieties later, it will be easier if the area and the number of plants in the trial plots is kept uniform.

During harvest, we were careful to cut the plants from the base and thresh the individual varieties separately. The straw from each variety was kept together, labelled, and dried. Once completely dry, they were weighed and the straw yield of each variety obtained separately.

F) Post-Harvest Processing

- *Cleaning:-* After harvest, the seeds and other planting material need to be cleaned, as the chaff and stem can harbour insects that may attack them during storage. The seeds can be cleaned by wet or dry methods depending on how they are found on the parent plant.
- *Wet cleaning:-* is used for those plants that carry their seeds in moist flesh, such as tomatoes, cucumbers, melons, and pumpkins. Scoop the seeds out of the flesh into a container of water and rub them vigorously. Collect the seeds with a sieve, and run water over them to remove the little bits of flesh. Afterwards, the cleaned seeds are spread out on a newspaper and dried in the sun for 5-10 days.
- If the seeds of the above mentioned crops are scooped out along with the pulp and left to stand for a few days in a container with water, the water will ferment. The action of yeast and bacteria during fermentation gets rid of some of the seed-borne diseases. This process cleans off the gelatinous pulp surrounding the seeds. The seeds are then washed in a strainer, spread out, and dried. However, the removal of the gelatinous layer covering the seed might make them vulnerable to pest attack.
- *Dry cleaning:-* This method is used to clean seeds maturing in a dry fruit, like capsule, pod, husk, as in legumes, cereals, vegetables like radish, carrot, onion, etc. Dry cleaning is mainly done by winnowing and handpicking. Winnowing separates chaffy grains and other debris from the fully formed, heavier seeds. Handpicking is a better option for larger seeds like beans.

Drying

Care should be taken to properly dry the seeds as they can be attacked and damaged during storage by fungi and insects. Some seeds may need to go through two drying processes. The first drying is done after harvest, inside the capsule or pod, to ensure that all the seeds are mature and the second, after winnowing. Generally large seeds need a much longer drying time than small ones. A simple test to see whether they are dry would be to take one seed and bite it hard. If it is soft and leaves an impression on the seed coat, it needs further drying. If it is hard and firm it is dry enough for storage. In the case of rice and other cereals, if the unhusked seed breaks with a brittle cracking noise when bitten, it means that they are dry and can be stored.

The optimum moisture content in seeds during storage is different in each crop variety. In paddy, the ideal moisture content is 12%-13%.

G) Traditional Seed Storage and Treatment

Second to breeding, the most important factor determining the vigour of a seed is the way it is stored. In storage, seeds are dormant and their life processes like respiration, are minimal. Seeds should be kept away from sunlight, excessive moisture, and should not be subjected to variations in temperature. Since light and moisture can trigger germination, seeds stored in dark containers have a longer life than those stored in the open. At low moisture levels they can handle fluctuations of temperature better. Excessive moisture in sealed storage containers will result in the seeds burning up their stored food, hence generating excessive heat leading to their premature death. Seeds with varying seeds coat thickness absorb moisture at different rates.

The seed storage containers should be at a raised level, like a platform, or on pillars to keep away rodents and termites. Care should be taken to keep the seeds free of insects and pests.

In India there are many traditional seed storage methods for different crops. Some of the storage and preservation techniques for crops from various parts of the country are listed below:

Grains and Pulses

In the case of cereals like rice and wheat, the properly dried seeds are stored in wooden boxes, containers made of woven or plaited straw, woven cane, bamboo, or reed, or in earthen storage urns. More recently, galvanized iron, plastic containers and gunny

quintals. Such containers are called *moda* in West Bengal, and *olia* in Orissa. These containers are sometimes plastered with mud and cowdung on the outside.

Another common method of grain storage is in bamboo/cane baskets which have lids. These are made by weaving together strips of bamboo flats. These baskets are called *doli* in Orissa and *deli* in West Bengal. In the Western ghats of Karnataka, they are called *kanaja* and are used to store more than 10 quintals of cereals. Similar containers are made in Garhwal from ringal (a locally available bamboo variety) and are called *dabla, solmundi*, or *konni*. The size and capacity of these baskets can vary from 10 kg to 5 quintals. These baskets are plastered on the inner and outer surface with cowdung and mud which absorbs the moisture and keeps the insects away. Since the crevices are filled up by the plaster, these baskets are used to store fine grains like amaranth. The Warli tribals in Maharashtra store their paddy seeds in cylindrically folded bamboo mats coated with dry grass and mud.

Clay pots and other earthenware containers of varying sizes are used widely all over India for storing seeds. Some large earthen containers, like the one in some parts of Orissa, is sealed with cowdung plaster on top and has an outlet at the base for removal of grains. In Karnataka, tall or medium sized, spindle shaped earthen containers are built into the wall near the hearth to keep them free of moisture. In the courtyards of some villages in Madhya Pradesh, storage containers made of earth or woven bamboo with mud plaster are used. These containers have a thatched roof and are built on a raised platform or on pillars.

Vegetable Seeds

These are usually stored above the fire in the kitchen inside hollowed dry gourds, cloth bags, or tin boxes. The smoke and heat from the burning wood keeps insects and moisture away. Dry bottle gourd is the most commonly used to store small quantities of seeds. These are called *thomda* in Garhwal.

Maize, Garlic and Onion

The best cobs of maize in their sheath are chosen, plaited and tied in bunches of 10-15 and hung from the roof of the driest room in the house, which is usually the kitchen.

Uprooted garlic and onion plants, with their dried leaf stalks are plaited together and hung from the eaves of the kitchen. The soot and smoke from the wood fire keeps insects away.

Tubers and Rhizomes

Special care has to be taken for tubers like potato and rhizomes like ginger as exposure to sunlight and excessive moisture can cause sprouting. But excessive dryness could cause dessication and eventually the death of the planting material. In some regions of India, like Kerala, storage of tubers in underground pits was a common practice. These pits were located in moderately dry soil and were plastered with mud and cowdung, or lined with coconut or banana leaves. However this method of storage is no longer widely practised. Tubers are also spread out in dry dark rooms, like stores and granaries. They should not be piled up as this can cause decay during storage. Tubers should be planted out as soon as the favourable season arrives.

Recalcitrant Seeds

Most tropical and sub-tropical fruit trees have seeds that cannot be dried without damaging their embryo. They need to be germinated as soon as the fruit is eaten. In natural conditions these seeds die quickly if they cannot germinate as soon as they fall on the ground. The germinated seedling can stay dormant for years until the arrival of favourable conditions.

Citrus seeds can be stored for upto 4 years in humid cold conditions. Moist sand has been found to be ideal for their storage. These seeds should not be allowed to dry up as they would die because of dessication.

H) Traditional Methods of Controlling Insects and Pests

In addition to ideal storage conditions, it is essential to protect the seed/planting material from storage pests and moulds as they can cause heavy damage. Listed below are some popularly used traditional pest control methods:

1. The grain/seeds may be periodically dried in the sun. Storage rooms may be smoked regularly to keep away storage pests like moths, weevils and beetles.

2. Wood, cowdung ash and sand may be mixed with the grain. One effect of adding these is that is they fill the inter-granular spaces and so restrict insect movement. Sometimes small cereals grains, such as millet and amaranth are added to maize, pulses and sorghum which is stored for seed.

3. Adding inert mineral dust and special types of clay (including activated charcoal and heat activated clay dust) to the grain is also practised. These scratch the thin water proofing layer which exists on the outside surface of the insect's body wall, causing a loss of water

and its death from desiccation. Wood ash and sand can also have this effect. Sometimes the powered dry rhizome of sweet flag (*vacha baje* in Kannada; scientific name: *Acorus calamus*) is also added.

4. A small clay lamp filled with oil may be lit and placed inside the storage container before it is sealed. The lamp will burn until the oxygen in the container is exhausted so that the insects also perish from lack of oxygen.

Traditional, Plant-Based Methods Of Insect Control

Many locally available plants, their extracts and ashes are used in different regions of India for treating the seeds. These arc usually aromatic or possess alkaloids, thus making them insecticidal or pest repellent. Given below is a list or commonly used pest control methods:

Black pepper: 5% black pepper keeps away rice weevils in rice and wheat.

Cinnamon: Raw bark attracts rice weevils, on addition of a few pieces to a sack of polished rice.

Eucalyptus: The action is similar to the above, when the bark is added to a sack of rice.

Fenugreek is mixed with grain in sacks.

Vitex negundo leaves are used to protect sorghum and pulses.

Neem leaf, fruit, seed are all used. 5 to 7 cm. thick layer is spread over a large quantity of grain. Powder made from neem seeds is widely used with stored products. The powder mixed with wheat at a rate of 10-20 gms/kg. protects the grains from weevils for almost one year.

Red Chillies protect rice against weevils. Burnt seeds were used to protect maize even 400 years ago.

Mint Leaves: Powdered leaves mixed with wheat at 5% gives good control over rice weevils.

Turmeric rhizome: 2% rhizome powder is mixed with wheat and rice.

Wild Tobacco: Dried, chopped leaves laid over the pulses protect it from bean weevil.

Plant extracts (oils): Neem, mustard and castor oils are said to control insects in pulses stored for seeds. The oil is mixed well, so that each seed is coated.

Ash: Ash of *Acacia, Casuarina*, mango trees, rice husk, tamarind seeds is mixed with grains to give a protective covering.

Twisted straw storage container with mud and cowdung plaster, from Chattisgarh, Madhya Pradesh

I) Community Seedbank and Exchange Networks

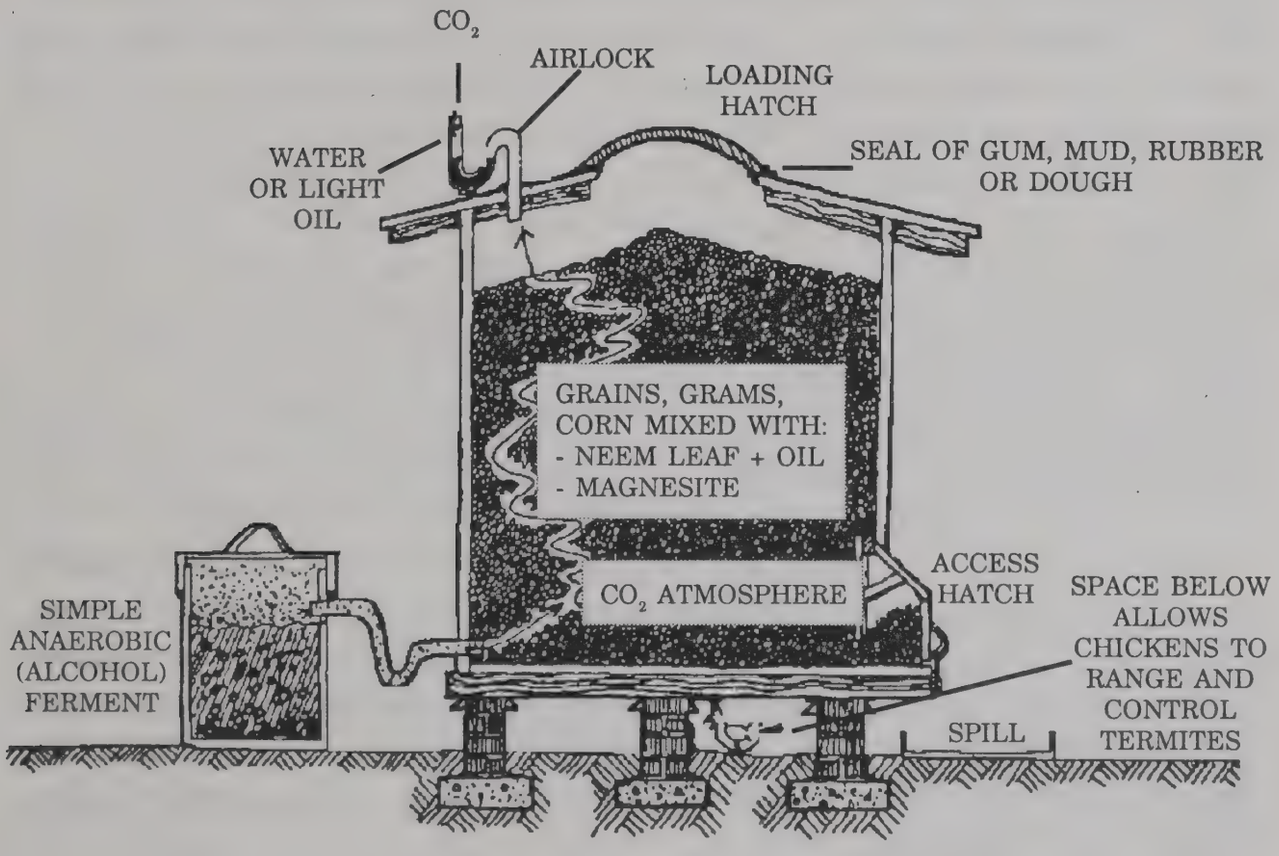
In many parts of the world, farmers have well established seed supply systems which often operate in a network. This includes the exchange of seed through local markets, as well as concerted efforts by Heritage seed programmes and organic farming groups, which provide an assortment of crops and their varieties. In India, the informal exchange networks like farmer to farmer exchange accounts for 80% of the seed required for planting. Historically, free exchange of seed/planting material within farming communities and between communities across regions, nations and even across continents has contributed to the abundant agricultural biodiversity that is available today. Indian agriculture was enriched with gifts of wheat from Central Asia: onion and orange from China; bean varieties, tobacco, peanuts, potato and cotton from Latin America; sorghum, finger millet, sesame, cowpea and coffee from Africa among others. In turn, India gave the world, rice, rapeseed, mango, tamarind, cucumber, brinjal and spices like cinnamon, cardamom and black pepper.

Reinforcing the free exchange between of biodiversity between farming communities becomes vital in the present context of appalling rate of erosion of agricultural diversity due to introduction of HYVs, ecological destruction and change in social values. The oppressive and unfair trade practices of GATT/WTO which allows large corporations to monopolize seeds through patents is further undermining farmers' rights as breeders, conservers and consumers.

Role of community seed banks

Navdanya envisions the conservation of agricultural biodiversity through a network of community seed banks in all the different ecozones of the country. Community seed bank networks facilitate farmer's seed exchange and supply systems. Such conservation through a network of community seed banks leads to the rejuvenation of:

1. Agricultural biodiversity as a common property resource
2. Farmer's self reliance in seed locally and nationally



GRAIN STORAGE SYSTEM

With its lid sealed with mud or tar, and with an air-lock for carbon-dioxide escape; a nearby ferment provides CO_2 which kills pests. Store is raised on stones to allow chicken control of termites.
Source: Permaculture—A Designer's Manual

3. Sustainable agriculture as foundation for food security both locally and nationally, and,

4. Farmer's rights as common intellectual rights of agricultural communities.

There has been a strand of thinking that community seed banks should be built only from local biodiversity and for local communities. Such a purist's stand prevents communities in areas depleted of biodiversity from rejuvenating their ecosystem and farm production. To limit community seed banks to build on only what exists locally is also to overlook how farmers have protected and increased local biodiversity through exchange across regions.

Navdanya's concept of a community seed bank is not merely local. A community seed bank can be a village community exchanging seed within itself or can be part of a regional, national or international network.

Community seed register: A tool for seed conservation

Seed conservation and exchange necessitates the documentation of agricultural biodiversity and maintaining a community seed register. A community seed register is the documentation of the crop genetic resources and knowledge of local communities at the local level, for the purpose of rejuvenating the ecological basis of agriculture and the economic status of the farmers. This should ideally be done by the local community or with the help of community organisations or NGOs. It reasserts farmers' collective rights and invests the custodianship of the local agrobiodiversity with the concerned farming community. These local registers can then be compiled into regional and national registers. These registers can be used in bringing out catalogues which carry essential information on the plant varieties available for exchange, sale and distribution.

Quality seeds and planting material of traditional crops needs to be made available to farmers and gardeners to wean our food system free of the dependence on the harmful chemicals used in modern farming. To announce their availability, the national catalogue compiled from the local community registers will be very helpful. The sale of these seeds can be through mail-orders or direct sale outlets in each agroecosystem.

Market Support for In Situ Conservation:

To prevent the erosion of agricultural biodiversity and for the continued use of traditional crops and their varieties, it is essential to have consumer motivated market support. For this, awareness needs to be generated on the nutritional superiority of the traditional

crop varieties which are invariably grown organically and are frugal ill their use of natural resources, unlike the hybrid crop varieties; which are increasingly being cultivated today. Consumers need to be informed of the difference in quality between crops grown traditionally and chemically cultivated crop varieties.

Consumer support is essential as an assurance for farmers to continue growing traditional varieties, and, in the long run, will lay the foundation for biologically diverse organic farming and the conservation of agricultural biodiversity. This will also bring about the much needed change in attitude in agricultural research and development. Such a shift in attitude will generate a corresponding shift in market trends that will benefit the traditional farmers as well as the consumers.

In the process of creating a market for organically grown, biologically diverse foods, the farmer and his family should not be impoverished. The market should be built on existing local marketing systems and should empower the farmers involved. The traditional agricultural systems and their marketing networks were highly supportive of diversity in the farmers' fields. The farmers in Garhwal Himalayas have been growing grain amaranth and buckwheat to exchange them for salt, rice, wheat or clothes, or sell it for money. Today due to the disintegration of local marketing systems for these two crops (which are fasting time foods for the plains people) and the farmers' growing dependence on the fluctuating urban markets to sell their produce, leaves them with no bargaining power. This results in poverty and leaves the farmer at the mercy of an impersonal market.

Traditionally, the farmer sold to the market only that part of the produce which was genuinely surplus, ensuring nutritious food for themselves. Modern agriculture not only destroys the farmers' economy but also impoverishes their diet by forcing them to grow cash monocrops like soybean, tomato, potato, etc., which displace the more nutritious traditional crops.

The consumer must be encouraged to participate in the farmers' economy by making choices that will not only encourage the cultivation of traditional crop varieties but also actively discourage excessive cash crop cultivation that use harmful chemicals, scarce resources and hybrid seeds. International agricultural bodies including FAO recognise the need for a responsible and active role to be played by the consumer market for successful and sustained biodiversity conservation. It is hopeful to note that many European countries are enforcing environmentally sound agricultural policies which recognize the need to conserve biodiversity in farming. All over the world, direct linkage between farmers and consumers are being cheerfully welcomed by ordinary people. These changes will pave the way for the continued and sustainable use of agricultural biodiversity.

APPENDIX 1

COLLECTION DATA SHEET

ACCESSION NO. .....
PHOTO NO. .....
DATE OF COLLECTION .....

1. COLLECTION SOURCE:
   (i) Village ..... Tq ..... Dist .....
   (ii) State .....
   (iii) Farmland/Threshing floor/Farmer's house or granary
   Farmer's name .....
   (iv) Village market/Seed fair .....
   (v) Bordering field/Wild
   (vi) Other source (specify) .....
2. TYPE OF SAMPLE:
   Seeds/Panicle/Vegetative
3. LOCATION/AREA FEATURES:
   (i) Soil type .....
   (ii) Climate .....
   (iii) Rainfall .....
   (iv) Altitude .....
   Land type ..... Upland/Lowland .....
4. CROP FEATURES:
   (i) Name of the crop .....
   (ii) Local name of the variety .....
   (iii) Meaning of the local name of the variety .....
   (iv) Cropping season .....Kharif/Rabi ..... (month to month)
   (v) Days to Maturity ..... (from sowing to harvest)
5. FARMING FEATURES:
   (i) Irrigated/Rainfed/Deepwater/Tidal wetland .....
   (ii) Sole crop/mixed crop .....
   (iii) Specific companion .....
   Crops (if any)
   (iv) Direct seeding/Transplanting .....

6. AGRONOMIC AND MORPHOLOGICAL FEATURES
   (i) Height of the plant .....
   (ii) Lodging/Non lodging .....
   (iii) No. of tillers .....
   (iv) No. of earheads/fruits .....
   (v) Distinctive vegetative features .....
   (vi) Germination .....
   (vii) Tolerance to drought during—
   Seedling stage .....
   Post emergence: Early days .....
   Mid days .....
   Late .....
   (viii) Pest resistance/tolerance .....
   Disease resistance/tolerance .....

7. YIELD PER UNIT AREA
   (i) Grain .....
   (ii) Straw .....
   (iii) Yield under ideal conditions .....

8. GRAIN/FRUIT FEATURES
   (i) Colour: Outer ..... Inner .....
   (ii) Fruit shape ..... Size .....
   (iii) Seed colour .....
   (iv) Aroma/smell .....
   (v) Taste .....
   (vi) Cooking Characteristics .....
   (vii) Threshing characteristics .....
   (viii) Pounding characteristics .....

9. STORAGE FEATURES
   (i) Traditional methods .....
   (ii) Max. years of storage .....
   (iii) Storage pest problem .....

10. CROP PREFERENCE: (why this crops is preferred) .....
   (Medicinal/Fodder or any other ethnobotanical value) .....

11. SHARE OF THIS CROP IN THE DAILY DIET .....
   (Local preparations) .....

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Variety of indigenous maize seeds from the Navdanya collection

Colonisation of the Seed

By Vandana Shiva

Whether we consider the chemicalization of agriculture through the green revolution or its transformation through the new biotechnologies, the seed is at the centre of all recent changes in agricultural production.

All technological transformation of biodiversity is justified in the language of "improvement" and increase of "economic value". However, "improvement" and "value" are not neutral terms. They are contextual and value-laden. What is improvement in one context is often regression in another. What is value added from one perspective is value lost from another.

The "improvement" of the seed is not a neutral economic process. It is, more importantly, a political process that shifts control over biological diversity from local peasants to transnational corporations and changes biological systems from complete systems reproducing themselves into raw material. It therefore changes the role of the agricultural producer and the role of ecological processes. The new biotechnologies follow the path of hybridization in changing the location of power as associated with the seed. As Jack Kloppenburg has stated, "It decouples seed as 'seed' from seed as 'grain' and thereby facilitates the transformation of seed from a use value to an exchange value."

Agricultural research is primarily a means of eliminating barriers to the penetration of agriculture by capital. The most important barrier is the nature of the seed, which reproduces itself and multiplies. The seed thus possesses a dual character that links both ends of the process of crop production: it is both means of production and, as grain, the product. In planting each year's crop the farmers also reproduce a necessary part of that means of production. The seed thus presents capital with a simple biological obstacle: given appropriate conditions the seed will reproduce itself manifold.

The seed has therefore to be transformed materially if a market for seed is to be created. Modern plant breeding is primarily an attempt to remove this biological obstacle to the market in seed. Seed reproducing itself stays free, a common resource and under the farmer's control. Corporate seed has a cost and is under the control of the corporate sector or under the control of agricultural research institutions. The transformation of a common resource into a commodity, of a self-regenerative resource into mere "input", changes the nature of the seed and of agriculture itself. Since it robs peasants of their means of livelihood, the new technology becomes an instrument of poverty and underdevelopment.

The decoupling of seed from grain also changes the status of seed. From being finished produce which rises from itself, nature's seeds and people's seeds become mere raw material for the production of corporate seed as commodity. The cycle of regeneration of biodiversity is therefore replaced by a linear flow of free germ plasm from farms and forests into labs and research stations, and the flow of modified uniform products as priced commodities from corporations to farmers. Diversity is destroyed by transforming it into mere raw material for industrial production based on uniformity, which necessarily displaces the diversity of local agricultural practice.

Cropping systems in general involve an interaction between soil, water and plant genetic resources. In indigenous agriculture, for example, cropping systems include a symbiotic relationship between soil, water, farm animals and plants. Green revolution agriculture replaces this integration of inputs at the level of the farm with the integration of inputs such as seeds and chemicals. The indigenous cropping systems are based only on internal organic inputs. Seeds come from the farm, soil fertility comes from the farm and pest control is built into the crop mixtures. In the green revolution package, yields are intimately related to purchased inputs of seeds, chemical fertilizers, pesticides, petroleum fuels and intensive irrigation. High yields are not intrinsic to the seeds, but are a function of the availability of inputs. According to the United Nations Research Institute for Social Development (UNRISD) 15-nation study of the impact of the new seeds, the term "high-yielding variety" (HYV) is a misnomer because it implies that the new seeds are high-yielding in and of themselves. The distinguishing feature of the seeds, however, is that they are highly responsive to certain key inputs such as fertilizer and irrigation. Palmer therefore suggested the term "high-responsive varieties" (HRVs) in place of HYVs.

As Claude Alvares has said, "For the first time the human race has produced seed that cannot cope on its own, but needs to be placed within an artificial environment for growth and output." This change in the nature of seed is justified by creating a framework that treats self-regenerative seed as "primitive" and as new germ plasm, and the seed that is inert without inputs and is non-reproducible as a finished product. The whole is rendered partial, the partial is rendered whole. The commoditised seed is ecologically incomplete and ruptured at two levels:

1) It does not *reproduce* itself, while, by definition, seed is a regenerative resource. Genetic resources are thus, through technological transformation, transformed from renewable into nonrenewable.

2) It does not *produce* by itself. It needs the help of inputs to produce. As the seed and chemical companies merge, the dependence on inputs will increase, not decrease. And whether a chemical is

added externally or internally, it remains an external input in the ecological cycle of the reproduction of seed.

It is this shift from the ecological processes of reproduction to the technological processes of production that underlies both the problem of dispossession of farmers and genetic erosion.

The new plant biotechnologies will follow the path of the earlier HYVs of the green revolution in pushing farmers on to a technological treadmill. Biotechnology can be expected to increase the reliance of farmers on purchased inputs even as it accelerates the process of polarization. It will even increase the use of chemicals instead of decreasing it. The dominant focus of research in genetic engineering is not on fertilizer-free and pest-free crops, but pesticide and herbicide-resistant varieties. For the seed-chemical multinationals, this might make commercial sense—since it is cheaper to adapt the chemical crop variety to the plant. The cost of developing a new crop variety rarely reaches US$2 million, whereas the cost of a new herbicide exceeds US$40 million.

Herbicide and pesticide resistance will also increase the integration of seeds/chemicals and the multinationals' control of agriculture. A number of major agricultural chemical companies are developing plants with resistance to their brand of herbicides. Soya beans have been made resistant to Ciba-Geigy's Atrazine herbicides, and this has increased annual sales of the herbicide by US$120 million. Research is also being done to develop crop plants resistant to other herbicides, such as Dupont's "Gists" and "Glean" and Monsanto's "Round-Up", which are lethal to most herbaceous plants and thus cannot be applied directly to crops. The successful development and sale of crop plants resistance to brand-name herbicides will result in further economic concentration of the agricultural industrial market, increasing the market power of transnational companies. The farmers will own the land, but the corporation will own the crop in the field, giving instructions by a computer that monitors the progress and needs of a crop grown from genetically programmed seed.

Biotechnology can thus become an instrument of dispossessing the farmer of seed as a means of production. The relocation of seed production from the farm to the corporate laboratory relocates power and value between the North and South; and between corporations and farmers. It is estimated that the elimination of home-grown seed would dramatically increase the farmers' dependence on biotech industries by about US$6 billion annually.

It also becomes an instrument of dispossession by selectively removing those plants or parts of plants that do not serve the commercial interests but are essential for the survival of nature and people. "Improvement" of a selected characteristic in a plant is also a selec-

tion *against* other characteristics which are useful to nature, or for local consumption. Improvement is not a class- or gender-neutral concept. Improvement of partitioning efficiency is based on the "enhancement of the yield of desired product at the expense of unwanted plant parts". The desired product is, however, not the same for rich people and poor people, or rich countries and poor countries, nor is efficiency. On the input side, richer people and richer countries are short of labour and poorer people and poorer countries are short of capital and land. Most agricultural development, however, increases capital input while displacing labour, thus destroying livelihoods. On the output side, which parts of a farming system or a plant will be treated as unwanted depends on what class and gender one is. What is unwanted for the better off may be the wanted part for the poor. The plants or plant parts which serve the poor are the ones whose supply is squeezed by the normal priorities of improvement in response to commercial forces.

In the Indian context, plants that have been displaced by plant improvement in the green revolution are pulses and oilseeds, which are crucial to the nutrient needs of people and the soil. Monocultures of wheat and rice spread through the green revolution have also turned useful plants into weeds, as is the case with green leafy vegetables which grow as associates. Herbicide use has destroyed plants useful for the poor, and pesticide use has destroyed the fish culture usually associated with paddy cultivation in the Asian rice farming system. These losses through biodiversity destruction resulting from increasing yields of monocultures are never internalized in the productivity measure of technological change. Instead, both increased inputs and decreased outputs are externalized in measurement of productivity. Productivity is a measure of output per unit input. A typical subsistence farm in an Asian village produces more than 20 crops and supports animals. Individual crops are also multi-purpose. Rice, for instance, is only partially food. The residue after removal of the grain is not a nuisance to be disposed of as it would be on a farm in the developed world. The straw is used to feed work animals, to cook food, or even to help fertilize the field for the next year's crops. The straw and husk are important construction material. Traditional rice varieties produced five times as much straw as grain, and were an important source of food, feed, fuel, fertilizer and housing material.

Plant breeders, however, saw rice only as food and created a science and technology to increase grain yields. Traditional crop varieties, characterized by tall and thin straw, typically convert the heavy doses of fertilizer into overall growth of the plant, rather than increasing the grain yield. Commonly, the excessive growth of the plant causes the stock to break, lodging the grain on the ground, which

results in heavy crop losses. The "miracle seeds" or "high yielding varieties" which started the process of green revolution were biologically engineered to be dwarf varieties. The important feature of these new varieties is not that they are particularly productive in themselves but that they can absorb three or four times higher doses of fertilizer than the traditional varieties and convert it into grain provided proportionately heavy and frequent irrigation applications are also available. They also have high susceptibility to insect and pest attacks.

For equivalent fertilization, the high-yielding varieties produce about the same total biomass as the traditional rice. They increase the grain yield at the cost of the straw. Thus while traditional rice produces four to five times as much straw as grain, high-yielding varieties of rice typically produce a one-to-one ratio of grain to straw. Thus a convergence from traditional to high-yielding rice increases the grain available but decreases the straw. Abundance creates scarcity. Output as total biomass does not increase, but the input increases dramatically. High-yielding varieties of wheat, for example, need about three times as much irrigation as traditional varieties. If water is considered a critical input, the productivity of the new seeds is only a third of the productivity of the traditional varieties. In terms of water use, the green revolution is clearly counter-productive. Increased irrigation intensity has further costs associated with it, in terms of water-logging and salinity, as experience in India's Punjab has shown. In other regions such as Maharashtra and Tamil Nadu, the green revolution is causing largescale mining of ground water. Largescale desiccation of the regions of the world now supporting the green revolution is thus a real possibility. Abundance again generates scarcity.

The increased water, fertilizer and pesticide use is also counter-productive for the Asian farmer in financial terms. From studies conducted at the International Rice Research Institute, it is estimated that whereas the total cash costs of production for the average Filipino rice farmer using traditional methods and varieties is about US$20 per hectare, the cost rises to US$220 when the new, high-yielding varieties are grown.

The fragmentation of components of the farm ecosystem, and their integration with distant markets and industries is a characteristic of modern "scientific" agriculture. The most common justification of the introduction of this system of food production is that it raises agricultural productivity. The high productivity of agriculture is however a myth when total resource inputs are taken into account. The social and ecological costs with respect to the manufacture and use of fertilizers, pesticides and labour- replacing energy and equipment are never taken into account, thus rendering the system artificially pro-

ductive. If the energy used to provide all inputs to modern farming is deducted from the food calories produced, modern agricultural technologies are found to be counter-productive. Whereas at the turn of the century, even in the countries of the north, one calorie of food value was produced by the input of less than a calorie of energy, so that there was a net gain, today 10 calories of energy are used to produce the same one calorie of food value.

The higher productivity and efficiency of industrial agriculture is contextually determined, by selecting those inputs and outputs which suit the endowments of rich people and rich countries. Before we push through new agricultural technologies, it would be wise to pause and look at the other paths that were available for increased production but were never considered. Alternatives in agriculture have been based on conserving nature and people's livelihoods, while improving yields, not on destroying them.

The myth that only chemically intensive, labour-displacing agriculture is productive has recently been challenged by a major study of the National Research Council in the US. The report, *Alternative Agriculture*, shows that besides reducing the health and environmental hazards posed by chemical agriculture, alternative farming systems have economic viability. Traditionally, most evaluations comparing chemical farming to alternative practices have focused principally on the cost and returns of adopting a specific farming method. Fewer studies have considered the impact of alternative farming systems on the economic performance of the whole farm. The committee could find no useful studies of the potential effects of widespread adoption of alternative agricultural systems, and no aggregate studies that compare the costs and benefits of conventional agriculture with successful alternative systems. Most studies have the flawed approach of comparing conventional farming practices with the economic performance of a similar farm, assuming withdrawal of certain categories of farm inputs instead of comparison with a farm using alternatives. The bias in favour of green revolution and chemical agriculture has distorted the assessment and potential of alternative agriculture. However, the new search for alternatives is showing that sustainable farming systems do not have to compromise at the level of productivity and yields.

A case study of the Thompson Farm established yields of 130-150 bushels/acre for corn against the national average of 124 bushels/acre, 45-55 bushels/acre of soya bean against the national average of 40 bushels/acre and 4-5 tons of hay against 3-4 tons/acre of the national average. Similarly, at the Kitamira farm the yield of 35.5 tons/acre of tomatoes was much higher than the country's average.

It is not only countries like the US which are making a shift away from energy- and chemical-intensive agriculture. In India, a

decade long experiment with *rishi kheti* or alternative agriculture undertaken at Friends Rural Centre in Rasulia, Madhya Pradesh by Pratap Aggarwal yielded higher returns, with indigenous seeds and no external inputs, than the green revolution agriculture of HYV seeds and heavy chemical and irrigation inputs which had been practised on the farm previously.

In the Terai region of Uttar Pradesh a local farmer called Inder Singh continued to grow traditional varieties while most farmers shifted to Pant-4, an HYV seed. As intensive irrigation led to a decline in the water table, the thirsty HYVs could no longer be cultivated. Inder Singh's seeds came in useful. Owing to high productivity and low costs of cultivation in terms of fertilizers and water input, a particular variety called Indarasan (named after Inder Singh) spread to cover nearly 50 per cent of the area. During drought years, Indarasan has coped much better than Pant-4, with yields of 32 quintals per acre compared to Pant-4 which has stagnated at 20 quintals per acre under irrigation. Without irrigation the HYV is totally destroyed. The Indarasan variety is also more remunerative in the market, selling at Rs 208 per quintal compared to Rs 175 per quintal for Pant-4.

In the Philippines on 29 May 1986, the MASIPAC Centre (Farmers and Scientists for Agricultural Science Development Centre) was inaugurated in Jaen, Nueva Ecya. The centre's programme is to build an agricultural alternative which is not dependent on capital and external inputs as the green revolution was.

Worldwide examples of successful alternative agriculture exist and are growing, even while they continue to be ignored by the dominant world view of agriculture. And it is these initiatives that carry the seeds of a sustainable agriculture. Blindness to these alternatives is not a proof of their non-existence. It is merely a reflection of the blindness.

Biotechnological Development and the Conservation of Biodiversity

The central paradox posed by the green revolution and biotechnological development is that modern plant improvement has been based on the destruction of the biodiversity which it uses as raw material. The irony of plant and animal breeding is that it destroys the very building blocks on which the technology depends. When agricultural modernization schemes introduce new and uniform crops into the farmers' fields, they push into extinction the diversity of local varieties. In the words of Garrison Wilkes of the University of Massachusetts, it is analogous to taking stones from a building's foundations to repair the roof. And as Brian Ford-Lloyd and Michael Jackson elaborate:

"Current international activities surrounding the genetic resources of plants aim to confront one paradoxical problem. This is that scientists throughout the world are rightly engaged in developing better and higher yielding cultivars of crop plants to be used on increasingly large scales. But this involves the replacement of the generally variable, lower yielding, locally adopted strains grown traditionally, by the products of modern agriculture—the case of uniformity replacing diversity. It is here that we find the paradox, for these self-same plant breeders are dependent upon the availability of a pool of diverse genetic material for success in their work. They are themselves dependent upon that which they are unwittingly destroying."

The paradox arises from the foundational errors of assignment of value and utility, which then make the "modern" varieties look inherently superior, whereas they are superior only in the context of increased control over plant genetic resources and a restricted production of certain commodities for the market.

The challenge of the 1990s is based on our getting rid of false notions of obsolescence and productivity which legitimize the extinction of large parts of nature and society. The push for homogenization and uniformity comes both from the transnational corporate sector, which has to create uniformity to control markets, and from the nature of modern research systems which have grown in response to the market. Since most biotechnology research is dictated by TNCs, the sought-out solutions must have a global and homogeneous character. TNCs do not tend to work for small market niches, but aim at large market shares. In addition, researchers prefer tasks that can be simplified enough to be tackled systematically, and that produce stable and widely applicable outcomes. Diversity goes against the standardization of scientific research.

However, more production of partial outputs as measured on the market and in a monoculture is often less production when measured in the diversity of nature's economy or people's sustenance economy. In the context of diversity, increased production and improved productivity can be consonant with biodiversity conservation. In fact it is often dependent on it.

There is, however, a prevalent misconception that biotechnology development will automatically lead to biodiversity conservation. The main problem with viewing biotechnology as a miracle solution to the biodiversity crisis is related to the fact that biotechnologies are, in essence, technologies for the breeding of uniformity in plants and animals.

Biotechnology corporations do sometimes talk of contributing to genetic diversity—as when John Duesing of Ciba Geigy states:

"Patent protection will serve to stimulate the development of competing and diverse genetic solutions with access to these diverse solutions ensured by free market forces at work in biotech ecology and seed industries." However, the "diversity" of corporate strategies and the diversity of life-forms on this planet are not the same thing, and corporate competition can hardly be treated as a substitute for nature's evolution in the creation of genetic diversity.

Corporate strategies and products can lead to diversification of commodities, but they cannot enrich nature's diversity. This confusion between commodity diversification and biodiversity conservation finds its parallel in raw material diversification. Although breeders draw genetic materials from many places as material input, the seed commodity that is sold back to farmers is characterized by uniformity. Uniformity and monopolistic seed supplies go hand in hand. When this monopolizing control is achieved through the molecular mind, destruction of diversity is accelerated. As Jack Kloppenburg has warned, "Though the capacity to move genetic material *between* species is a means for introducing additional variation, it is also a means for engineering genetic uniformity across species." Production is thus driven in the direction of destruction of diversity. Production based on uniformity becomes the primary threat to biodiversity conservation, even though in the convoluted political economy of the market it is cited as the reason for conservation. The exploitation of genetic diversity for crop improvement should be the ultimate objective of the exploration and conservation of genetic resources, it is argued. The arbitrary inequality created in the status of germ plasm creates an arbitrary separation between production and conservation. Some people's germ plasm becomes a finished commodity, a "product", other people's germ plasm becomes mere "raw" material for that product. The manufacture of the "product" in corporate labs is counted as production. The reproduction of the "row" material by nature and Third World farmers is mere conservation. The "value added" in one domain is built on the "value robbed" in another domain. Biotechnological development thus translates into biodiversity erosion and poverty creation.

The main challenge to biodiversity conservation is the removal of reductionist blinkers which make more look less and less look more. The social construction of growth and productivity is achieved (1) by excluding crops and parts of crops as unwanted and (2) by creating a false hierarchy of resources and knowledge, splitting diversity into dichotomy.

Not till diversity is made the logic of production can diversity be conserved. If production continues to be based on the logic of uniformity and homogenization, uniformity will continue to displace diversity. "Improvement" from the corporate viewpoint, or from the view-

point of Western agricultural research is often a loss for the Third World, especially the poor in the Third World. There is therefore no inevitability that production acts against diversity. Uniformity as a pattern of production becomes inevitable only in a context of control and profitability.

All systems of sustainable agriculture, whether of the past or the future, are built on the basis of the perennial principles of diversity and reciprocity. The two principles are not independent but interrelated. Diversity gives rise to the ecological space for give and take, for mutuality and reciprocity. Destruction of diversity is linked to the creation of monocultures, and with the creation of monocultures the self-regulation and decentred organization of diverse systems give way to external inputs and external and centralized control. Sustainability and diversity are ecologically linked because diversity offers the multiplicity of interactions which can heal ecological disturbance to any part of the system. Non-sustainability and uniformity mean that disturbance to one part is translated into a disturbance to all other parts. Instead of being contained, ecological destabilization tends to be amplified. Closely linked to the issue of diversity and uniformity is the issue of productivity. Higher yields and higher production have been the main push for the introduction of uniformity and the logic of the assembly line. The imperative of growth generates the imperative for monocultures. Yet this growth is, in large measure, a socially constructed, value-laden category. It exists as a "fact" by excluding and erasing the facts of diversity and production through diversity. Sustainability, diversity and decentred self-organization are therefore linked, as are unsustainability, uniformity and centralization.

Diversity as a pattern of production, not merely of conservation, ensures pluralism and decentralization. It prevents the dichotomizing of biological systems into "primitive" and "advanced". As Gandhi challenged the false concepts of obsolescence and productivity in the production of textiles by his search for the spinning wheel, groups across the Third World are challenging the false concepts of obsolescence in agricultural production by searching for seeds used by farmers over centuries and making them the basis of a future-oriented, self-reliant and sustainable agriculture. (Taken from, *Biopolitics,* edited by Vandana Shiva and Ingunn Moser. 1995. pp 199-208).

Food Security—Kitchen Gardening

By Bernard Declercq

Introduction

The issue of food security is dominating all debates in big and small conference rooms. It is the topic of our times. The question is whether conference rooms will produce more food or not? (They certainly consume a lot!)

If we start a vegetable garden we will have contributed immensely towards our own and everybody else's food security and food safety. Every household should have a kitchen garden, even in urban areas. We can grow fresh organic vegetables on our roof top, balcony or even in a few pots on the window sill. For urbanites it will be relaxing to spend some time with plants. It will help to set aside those psychological stresses or sorrows. It is better exercise our lungs and muscles. Let us feel young again and fill up those few pots with dirt or start a patch and let us grow happiness.

The difficulties urbanites face are things like leaking terraces, embarrassment to carry crates and other rubbish upstairs etc. With a little goodwill all these difficulties can be overcome.

For instance one can spread a plastic sheet on the terrace to put the crates, flower pots or old cement bags filled with soil and leaves. In cities there is the danger of exhaust fumes—we must be careful about that ! In fact, it is relatively easy to grow vegetables in urban areas.

But the main difficulty is to grow vegetables in the villages, for rural households!

Double dug bio-intensive gardens, providing lots of high quality vegetables for the family kitchen are relatively easy to establish in the villages. But where resources are limited, one can try a circle garden!

A circle of 1m. diameter has a circumference of over 3m! The concept of a circular garden (D.G. Langham) allows thus to grow many plants in a small space. Such a small kitchen garden close by the house can be an important step to combat mall nutrition or wrong nutrition in the villages and also provide herbs for health care.

Why a Kitchen Garden ?

- To get fresh and nutritious vegetables, fruits, herbs, etc.
- To have safe food, free of pesticides and other chemicals

- To make productive use of waste water and other wastes from home, garden, cowshed
- To save money on the purchase of vegetables and fruits
- To create a healthy and beautiful environment around the living space
- To enjoy contact with nature, be in touch with plants, the earth

There are many more reasons to start one's own garden. There are social/personal reasons as well such as independence, self confidence, etc.

The Problems

There are of course some constraints in the villages that can make the adventure of gardening difficult. Difficult but not impossible. Some of the difficulties are:

- Lack of space
- Stray cattle and goats
- The neighbours' chickens
- Street dogs, etc.
- Lack of water in the dry season
- Lack of seeds

A circle garden can meet with most of these hindrances. But a network of centers who are involved in promoting kitchen gardening is essential (e.g. to make suitable seeds available for the gardeners).

How to make a circle garden?

1. Design a circle of 1m diameter on the soil. Take a twig or small piece of rope. Hold it against the lower arm, hand outstretched. This will give a measure of about 45 to 50 centimeters, the radius. Put a stone or small stick where the center of the circle will be. Use the measure and mark the circle on the ground. Draw another circle around the first one, with a distance of about 20 cm. between their circumferences. To do that imagine the first circle to be a watch. Put a small dot of ash 20 cm. above 12 o'clock, next to 3 and 9 and below 6 o'clock. Connect the dots with a circular line. In this way a circular strip appears. Use some ashes to make the design more prominent.

2. Loosen the soil thoroughly inside this circular strip of ± 20 cm diameter. Eventually use a crowbar or other local implement.

3. Move the earth from the center of the circle towards the loos-

ened strip. Heap the soil up so that a small ridge is formed. This creates a small pit inside the circle, while a circular ridge is formed on top of the loosened strip. In this way a very deep loose soil is created, ideal for root penetration.

4. Flatten the ridge lightly by hand and create a slope of 45° on the sides.

5. Trace a furrow with the finger or a stick on the inside of the circle ridge at the original soil level. Plant seeds or transplant seedlings in this furrow.

6. Pour, if needed, a little water in this furrow before seeding or transplanting. Take an odd number of seeds or plants (3, 5, 7, 9, etc.).

7. On top of the ridge a zigzag line can be traced with the finger. This will form a small furrow and it can be used to sow short duration vegetables (e.g. green amaranths or radish.).

8. After the planting is done, it is very important to pour one or two buckets of water in the circle. Afterwards it is sufficient to keep the "garden" moist, say by washing one's hands in the circle, etc.

9. In the pit at the center of the circle collect all kinds of organic wastes, some animal droppings, leaves, wastes from the kitchen, twigs, weeds, pieces of unprinted paper, etc. Introduce earthworms if necessary.

10. Throw some papaya seeds on this mini compost pit or later plant a banana.

11. Collect flat stones or broken tiles and put them up on the outer side of the ridge. This will reflect heat and will thus keep the ridge cool and moist.

Some Points to Consider

• Choose the place for the circle garden carefully, preferably close to the house door or cooking place and also avoid too much shade. It should be easy to keep an eye on it, etc.

• Never step on the ridge. Remember, the loose soil is an ideal place for root development. Try to bring as much variation in the circle gardens as possible. Combine different vegetables (companion planting) and vegetables and herbs. Catch some lady birds or praying mantis and place them in the circle. Keep up a good relation with them. They in return will take care of the pest problems.

• In fact a circle garden can be seen as a clock. So if one chooses to plant even numbers, that is not so difficult. Plants however seem to grow better in odd numbers. So to obtain 5 plants at equal distance,

(12 divided by 5 = 2h. 24') plant every 2 hours 24', for 7 plants every 1 hour 43', for 9 every 1 hour 20', and for 11 every 1 hour 05'. The distance between plants in a circle garden is the same as in a normal garden but in fact it could also be closer.

• The distance between two circle gardens is two meters, measured from center to center.

Here are some examples to start with:

• Corn, beans, cucumber, amaranths, papaya and cassava

Plant 9 corn (maize) seeds in the circle. Plant 3-5 beans and 1-3 cucumber seeds between the maize. Design a zigzag line on the ridge and sow leaf amaranths. Plant also 3 cassava sticks in the ridge giving equal spacing (e.g. at 12, 4, and 8 o'clock). Throw papaya seeds in the middle.

• Tomatoes, onions, marigolds

Plant 3, 5, or 7 tomato plants in the circle (number depends on variety chosen). Plant onions and a few marigolds between the tomatoes. In the zigzag line sow methi, radish, coriander or greens.

Plant Protection

If needed one can fence the circle garden. Push some thorny sticks in the soft soil on the outer side of the ridge. One can make a basket-like structure by weaving more thorny branches horizontally between (through) the sticks. Cover the basket also with thorny branches. No cows or goats or chickens should be able to get in.

Crush a handful of neem seed kernels and mix with half a liter of water. Keep this soaking overnight. Add 2–3 liters of water to this solution, a little soft soap and sprinkle it on the plants. To keep ants away, make an infusion with mint, lantana or other plants from the mint family. Add some crushed ginger and some chilli powder. Mix the preparate well and spray after some time.

Try a few gardens and with some experience one will be able to produce a lot with very little.

And really all what it takes is half an hour to set up a kitchen garden. One can also make bigger circles of 2 meters diameter for papaya and banana. By putting some small poles in the ground between the papayas and joining them with branches and leaves, one can create a private bathroom–circle garden. Put a few flat stones in the middle and have a nice bath!

Section IV

Problems in Plant-Insect-Animal Relationships

Section editor: K Vijayalakshmi

Insect pests have become the burial ground of modern chemical-based agriculture. In several areas of the country, inability to control pests through deadly poisons is forcing farmers to commit suicide. So the question to ask is: Who is trying to kill whom?

It is important to emphasise that pests do not exist in nature as such. Nature did not create pests to unnecessarily harass human beings. Nature has only created insects. These have their own specific niches in the ecosystem of the planet.

It is human beings who have by their actions—wittingly and unwittingly—transformed insects into pests. There is an English proverb which says: "Give a dog a bad name and kill it." We define insects as pests so that they can be legitimately killed in all manner of ways. Modern agriculture has become a vast killing field and those engaged in the production of food are paradoxically required to use poisons that directly threaten life. The vocabulary of modern agriculture can be reduced to a few basic terms one of which is the term 'cidere' which means "to kill". Thus we have weedicides, fungicides, pesticides, rodenticides and insecticides.

The problem is that even those who continue to recommend the usage of toxins to eliminate pests acknowledge that the strategy has continued to fail ever since it was first tried out. Nature is able to equip insects with resistance within a couple of years to overcome any of the toxins unleashed on them by scientists.

In the meanwhile, this widespread killing of pests by universal sprays of toxins and cocktails of toxins has had the effect of destroying beneficial insects and aiding the evolutionary survival of the hardier, more harmful ones. Since insects and we are part of the same web of life, it is also only natural that the poisons we use against them must rebound to affect us as well.

It would thus appear to any neutral observer that the use of such toxins in agriculture is a prime example of an extremely primitive and crude manner of dealing with nature. It cannot be called "science" by any conception of the imagination and the practice is best left behind by the human species if it wishes to move ahead.

In the section that follows, the eminent environmentalist Sunderlal Bahuguna addresses the question of how the toxins that we release in nature are coming back to harm human beings. "The Way to Survival" is actually the text of the inaugural lecture that Bahuguna delivered at the southern regional seminar on Biological Methods of Pest Control organised by the P.P.S.T. in 1988.

In the piece that follows, three Ayurvedic scholars provide basic information on pest management in Ayurveda. They show that Ayurvedic strategies for dealing with illnesses of plants are similar to Ayurvedic strategies recommended for illnesses of human beings. Ayurveda is based on the concept of balance of qualities and disease is seen as imbalance of such qualities. Healing is redressal of balance..

The third article, "Notes on Certain Commercially Available Biological Control Agents" introduces several new sources of natural predators and their uses for insect control.

My own piece (with N. Raja) on "Spiders and the Paddy Ecosystem" which concludes the section argues that spiders are a useful non-toxic method of controlling undesirable insect populations in paddy ecosystems. Those who wish to have more information on this, may wish to see my earlier book on this subject entitled "Spiders".

The Way to Survival

By Sunderlal Bahuguna

We are living in a world where human beings have adopted a lifestyle which in the name of progress and development is taking us towards death and destruction. This process started when the Industrial Revolution in Europe made two basic changes in human thinking about nature and man. Nature was regarded as a commodity and society only the society of human beings. Thus, the objective of development became the exploitation of nature for the benefit of human beings alone, ignoring other beings. The direction of science and technology was influenced by this thinking. Scientific research unfolded the mysteries of the physical world and human greed developed a technology to exploit nature. All the hidden treasures of nature were plundered in no time with the help of technology. This is how the prosperity, of which modern civilization boasts, has been achieved.

We had been blessed with four renewable resources—the grasslands, forests, crop lands and oceans—over which all life on this planet subsisted. It was not only the non-renewable resources like metals and minerals, which became the victims of human greed, but these renewable resources also became non-renewable due to over-exploitation. The whole concept of green revolution, applying the industrial practices of industry to agriculture, is a living example of the exploitation of croplands. Chemical fertilizers became the main components in agricultural production. The application of chemical fertilizers ignores this truth that soil is not dead matter, but a community of living things: bacteria, earthworms etc are the members of this community. In the traditional method of organic farming, where cowdung, green manuring and leaf-fertilizers were used, this community prospered. But when these materials were replaced with chemical fertilizers the living elements of the soil became extinct.

Today our farms have become addicts. Nothing can be produced till the farmer satisfies the farm's devilish demand for chemical fertilizers. The analogy of the human body applies to the soils. When the human body loses strength, it cannot resist disease. Similarly with soils weakened by the application of chemical pesticides. When chemical pesticides are applied, other living beings which in a natural system control the pests and maintain the ecological balance, become victims to the poisons. The extinction of frogs, snakes and owls is a glaring example of this. Everybody is familiar with the role of frogs and snakes in controlling pests, but very few know about the owl. Dada Salim Ali once remarked to me: "Do you know how useful the owl is to us?" I said: "Dada! You in your blind love for all birds eulogise even nasty birds like the owl." Dada replied: "My conclusions are based upon scientific studies, which I conduct watching the

behaviour of this bird. An owl preys upon at least three rodents in a night. A pair of rodents reproduces seven hundred in a year. It is said that five rodents destroy as much food as is enough to feed a person." I realised why our ancestors honoured the rodent by making Lakshmi (the goddess of wealth) ride on it.

I remember when Community Development Projects, borrowed from America, were first launched in the early fifties, zinc-phosphate was distributed to kill the rats. The rats died, but with this the cats also disappeared and vultures—nature's scavengers—also died.

But do the pesticides actually protect the crops? I leave this to the scientists, but I have read a recent report about farmers launching a stir in Ganga Nagar district of Rajasthan. This area is also a centre of the Green Revolution, as it was the first beneficiary of Rajasthan Canal. Crops worth millions were destroyed during the current Kharif season due to the application of pesticides. The pesticides manufactured by factories in Fatehabad in Sirsa (Haryana), which were supplied to these farmers, were found harmful and have now been banned. The farmers are now demanding compensation for the loss of crops.

The disastrous effects of pesticides on human health are now well-known. In the West, where people have become very conscious about the poison in food, a number of pesticides have been banned, but these are being popularized in poor countries. There 'Natural Food Stores' which supply food including fruits and vegetables produced by organic farming, are becoming so popular and important that I have seen these along with medical stores. The demand for these organic foods is so high that a few years ago I met a Swiss farmer in Berne, whose farm products were sold within few minutes. City people, with their shopping bags stood waiting for the arrival of his horse cart. Masanobu Fukuoka, the father of natural farming, who deserves to be called "Krishi Gandhi", spoke about the high demand for oranges grown on his natural farm.

The main causes for the quick expansion of the unnatural farming system have been:

(1) Human greed to have more consumer goods, and

(2) The population explosion.

Though in poor countries the Green Revolution is eulogised by saying that millions would have died of hunger without it, in affluent societies where over-production has become an economic problem there is no justification for it. The main reason for adopting the exploitative farming system is to achieve the affluence which has become the symbol of progress. Agriculture was culture. (The meaning of culture is sublimation of nature for the achievement of peace, happiness and fulfillment for all creatures). But now it has become a

commercial venture; otherwise the sugarcane farmers of western U.P. and Terai region and wheat farmers of Punjab, and Haryana would not have switched over to eucalyptus farming which has now proved economically disastrous. The main force behind unnatural farming is the industrial interest. Farmers today have become solely dependent on outside inputs and thus most of their earnings goes to the industrialists. They have become the bonded labourers of the industries and bankers. This was first realized by the farmers in Mexico, where they could not bear the burden of bank loans and were uprooted from the soil. Now one fourth of the population of Mexico is concentrated in Mexico city. Farmers in many South-East Asian countries, specially in the Philippines, are realizing that their earnings are going to fertilizer and pesticide industries and the banks. The symptoms of this are visible in India today. The farmers demand to write off the loans and for more subsidies is a clear indication of this. No government shall be able to solve this problem. There is no wonder if more and more distressing reports of farmers' suicides—like those from cotton farmers in Andhra—are reported.

The other aspect of this problem is more frightening. Our farming system has become more and more water-consuming. The worldwide scarcity of water is an established fact. According to World Watch Institute studies, per capita availability of water by the end of this century will be 24% less compared to 1983. India is on the margin. How quickly the availability of water is decreasing is clear from the figures given by Madhav Chitale, Chairman of the Water Commission. Per capita availability of water in India in 1901 was 9404 cubic meters. It came down to 6,972 cubic meters, i.e., approximately 26 per cent less, in 1941, and 3,243 cubic meters in 1981, i.e., 65 percent less. Even if the rate of decrease remains static, per capita availability in 2001 will be 14 percent when compared to 1901.

It is not only for irrigation that unnatural farming needs more and more water (150 lives are lost on an average every year in Tanjore district, the bread basket of Tamil Nadu, on account of water disputes) but fertiliser plants consume excessive water. The fertiliser plant of the Gujarat State Fertilizer Corporation, the refinery adjacent to it and the plant of Indian Petro Chemicals Ltd., consume every day 350 lakh gallons of water, which means 117 lakh pots of drinking water every day. Considering average consumption of even 10 pots a day per family, this water can meet the needs of 11.70 lakh rural families.

Humankind today is in search of viable alternatives, because the existing exploitative system which is the outcome of modern man's aggressive behaviour towards nature, has threatened the survival of all life on this planet. Scientists have predicted that by the end of this century 15 million plants and other species will become extinct.

The United Nations Commission on Environment and Development in its report, "Our Common Future" has summed it up this:

"Settled agriculture, the diversion of water courses, the extraction of minerals, the emission of heat and noxious gases into the atmosphere, commercial forests, and genetic manipulation are all examples of human intervention in natural systems during the course of development. Until recently such interventions were small in scale and their impact limited. Today's interventions are more drastic in scale and impact, and more threatening to life support systems both locally and globally. This need not happen. At a minimum, sustainable development must not endanger the natural systems that support life on earth, the atmosphere, the waters, the soils and the living beings...Maximum yield must be defined after taking into account system-wide effects of exploitation." The report suggests that, "future increases in productivity in both developed and developing countries should be based upon the better controlled application of water and agro-chemicals as well as more extensive use of organic manures and non chemical means of pest control."

But biased science, which is a tool in the hands of short-sighted politicians impatient to show miracles during their short tenure, and greedy industrialists, will not change its direction easily. We need a revolutionary change in our thoughts and action. There is darkness all around, but amidst this darkness the small organisation called the "Patriotic and People-Oriented Science and Technology Foundation" (PPST), is a ray of hope to travellers like me who are in search of alternatives to the existing system. We are living in a world, where 400,000 scientists are busy in war-research and Rs.210 millions per minute are spent on machines for killing people. This is only about those who are engaged in efforts for direct killing. If we add to it all those who are busy in exploitative research, the number will rise to millions. So the question arises, can such small organisations like PPST and isolated researchers like Vijayalakshmi and others, be able to divert the flow from death of life. And my reply is "Yes!" I say this with full confidence, because there is the historical evidence behind my conviction.

All through the long course of human history, there have been creative personalities like Buddha and Christ, Lenin and Gandhi, who were responsible in bringing about change. In modern India, the process of change had started with renaissance which was pioneered by Raja Ram Mohan Roy, nurtured by great personalities like Rabindranath Tagore, Jagadish Chandra Basu and finally popularized by Mahatma Gandhi; but we were disillusioned by the glitter of materialistic civilization and the march of renaissance temporarily came to a halt. With the worldwide realization of the destructive aspect of materialistic civilization, a suitable atmosphere for the ad-

vancement of renaissance has been created. Local dedicated groups of humanitarian scientists, social activists and compassionate literary men, artists and journalists will be the pioneers of change. They are the symbols of Gyan (knowledge—scientists), Karma (action—social activists) and Bhakti (devotion—literary men) and the message of our philosophy is that the success of Yajyan (noble action) lies in the combination of Gyan, Karma and Bhakti.

We should not wait for big names and big organisations. I am reminded of a poem of gurudev Rabindranath Tagore. Once Surya (the Sun-God) said, "I wish to take rest. Is there anybody to take over my job?" Everybody was afraid. "How can we replace such a powerful personality like the Sun-God?" A small lamp (deepak) came forward saying, "Sun-God! You take rest. I will continue burning in your absence." This small light became the ray of hope to those groping in the dark and a source of inspiration to those busy searching out a new path. I have been wandering for several years in the remote corners of this country and in many parts of the world. I have met several such small lamps, who have been spreading light all around them. There are people like Masanobu Fukuoka who are now well-known, but most are less known. Since they are swimming against the tide, they are facing ridicule, neglect, isolation and insult. I have a vast treasure of these and this is what I have with me to offer to you.

But I can assure you that, though a creative minority, you are the pioneers of a new era of peace, happiness and fulfillment to all living beings over this planet. Your course of action has been aptly put by the great historian Arnold Toynbee in these words.

"The growth of a civilization lies in the hands of a creative minority. The elite must have the power not only to cope successfully with the challenges to which their society is exposed, but also to carry along with them the majority of uncreative people." We are marching from "Death to Life" and our slogan is Yes to Life, No to Death.

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Plant Diseases and their Treatment in Vrkshayurveda

By K Vijayalakshmi, A.V. Balasubramanian and Vaidya K.M. Shyam Sundar

India is the repository of one of the richest bio-genetic resources in the world. Our countrymen have traditionally shown a remarkable awareness and knowledge of its varied flora and have in addition put it to diverse uses. In ancient India there was a tradition of classifying and grouping arts and crafts and knowledge into various types known as Sastra or Kala. Sage Vatsyayana, for example, in his famous Kama Sutra, listed 64 arts which is considered a standard list!

There are several such lists available and in these lists, along with subjects such as medicine or agriculture, there are various other sastras listed that bear a relation to plants, such as:

- Vrkshayurveda yoga—Treatment for Plants
- Buruhaanaam dohada—the Art of Grafting Trees
- Vrksharohanam—Growth of Trees
- Pushparthoranam—Decorations with flowers, etc.

In general the word Vrkshayurveda (literally meaning the "Science of Life of Plants") is used to denote knowledge of plant life in all its varied aspects.

Scope of Vrkshayurveda

Since the knowledge of plant life is so vast, so is the scope of Vrkshayurveda. It encompasses areas such as collection, selection and storage of seeds; germination, sowing, various techniques of plant propagation, grafting, nursing and irrigation; testing and classification of soil and selection of soils suitable for various plants/types of plants; manuring; pest and disease management/preventive and promotive care to build up disease resistance and to cultivate healthy plants; nomenclature, taxonomy, description and classification and description to suit varied purposes; favourable and unfavourable meteorological conditions for various plants, and use of plants as indicators of weather, water, minerals, etc.

This article highlights a few aspects related solely to plant diseases and their treatment.

Plant diseases in Vrkshayurveda are broadly of two types—exogenous and endogenous. The endogenous diseases are caused by the disturbance of the three *doshas,* namely *Vaatha, Pitta* and *Kapha.* The exogenous diseases are caused by factors such as pests, cold,

hail, lightning, etc. According to Vrkshayurveda, plants are also understood as having Vaatha, Pitta or Kapha characteristics, like human beings. We should have an overview of this concept to understand plant diseases.

Prakrithi or Constitution of Plants

Plants can be classified into three types based on their constitution. The broad classification is the same as the classification for human beings, namely, *Vaatha, Pitta* and *Kapha* constitution. The general characteristics of plants of each of these types are listed below.

Characteristics of Plants with Vaatha Constitution

- Slender and tall
- Light in weight
- Have a rough surface
- Their leaves wither or drop away with the slightest heat of the sun.

Characteristics of Plants with Pitta Constitution

- Are able to withstand bright light
- Have weak branches which break away easily
- Have abundant leaves and flowers
- Bear untimely fruits
- Are of medium size and height

Characteristics of Plants with Kapha Constitution

- Possess stout and bulky stems and branches
- Plenty of thick leaves
- Bear abundant flowers and fruits
- House many creepers and climbers around them

Rationale of Plant Prakrithi: A Comparison with the Human Constitution

According to *Ayurveda, Vaatha Prakrithi* individuals possess a slender and tall body, are light in weight, have rough and dry skin with prominent (bony) joints and present an emaciated look. *Pitta Prakrithi* individuals possess a medium-sized body with medium strength, have a tendency to early baldness and greying of the hair,

possess yellow or copper coloured skin and have plenty of pimples and freckles on the skin. *Kapha Prakrithi* individuals possess a short and bulky body with good strength and withstand stress better than the other two types of constitution. They have abundant seminal fluid and therefore are blessed with many offspring. They adjust well with all types of people.

Just as the case of humans, it is also true in the case of plants that single prakrithi type is very rare and what one normally encounters are combinations (e.g.) Vaata-Pitta type. Pitta-Kapha type, Vaata-Kapha, etc.

Vaathaja Diseases

Causes

Feeding plants excessively with substances that are dry and astringent vitiates *Vaatha. Vaatha* is also vitiated during summer as a result of loss of moisture in the soil.

Symptoms

Plants affected by *Vaathaja* diseases are lean, deformed, full of knots and globules on the leaves, rough, have low water content and exhibit a loss of sweetness.

Treatment

- Irrigation with flesh, fat, tallow and ghee could be one.
- Fumigation with neem, cow's horn, horse's hair, ghee, Ativisha. Aconitum oil, pig's fat, *Asparagus racemosus* and *Pinus deodara* could be attempted.
- The tumours and protuberances which develop on the sides of the trees due to *Vaathaja* disorders could be plastered with cowdung, marking nut and fat and watered with carrion broth.
- An infusion of Rasna, *(Plachea lanceolata)*, Ashwagandha or winter cherry *(Withania somnifera)*, Naga kesara (*Mesua nagassarium)* and long pepper *(Piper longum)* is used to water the plants.
- If conditions are acute, the tree is watered with an infusion of Dill or Shatapushpa *(Foeniculum vulgare, Anethum graveolens)* seeds.
- Fumigation with the leaves of five-leaved chaste trees Nirgundi *(Vitex negundu)*, Guggulu *(Commiphora mukul)*, ghee and seeds of *Terminalia tomentosa*, is also done.
- Dressing of the roots with goat's excreta and oil cake is also beneficial.

Rationale

The line of treatment for *Vaathaja* disorders in human beings is that therapy is done with ghee, fat, marrow, flesh, etc. The drugs administered should have the properties associated with them in Ayurveda, i.e. be sweet, sour and salty in taste, hot in potency, etc. Infusion and poultices are also done to reduce the pain which is characteristic of *Vaatha* dosha. The therapeutics is predominantly what is known as "bulk promoting". Drugs such as *Aswagandha, Rasna, Ballataka (Semicarpus anacardium), Shatapushpa* and *Nirgundi* possess these qualities. *Shatapushpa, Devadaru, Aswagandha* are also mentioned in Charaka for treatment of Vaathaja disorders.

Pittaja Diseases

If plants are irrigated with substances that are pungent, sour and saline it vitiates *Pitta.* Plants are also prone to *Pittaja* diseases in summer and autumn.

Symptoms

Yellowish discoloration of leaves, premature fruiting, oozing in fruits, emaciation due to excess activities of *Pitta*, subsequent burning up of body elements, languor of leaves and flowers and fruits bearing a worn-out appearance, are the symptoms of *Pittaja* diseases.

Treatment

- The plants should be irrigated with substances that are cooling and predominantly sweet in taste.
- Decoction of Yashti or Sweet Liquorice *(Glycyrrhiza glabra)*, Mahua tree *(Madhuca indica)* and milk mixed with honey is used for irrigation.
- Decoction of Triphala mixed with ghee and honey is also recommended. The plants could be nurtured with cold and perfumed Rose water in which sugar and Vidanga have been dissolved.
- Fumigation with sugar, honey and ghee is also suggested.

  Treatment is also given with Cuscus grass, nut grass, honey, milk and ghee.

Rationale

The line of treatment of *Pittaja* disorders is the use of drugs which are predominantly sweet, bitter and astringent in taste, cooling and those which are soft and viscous. Substances such as ghee, milk and butter are used extensively. Application of fumes from aromatic substances such as Chandana *(Santalum album)*, Usira, etc., is also beneficial. All that is soft and cold in nature is recommended.

Kaphaja Diseases

Causes

Irrigating plants excessively with substances that are sweet, unctuous, sour and cold, can cause *Kapha* diseases. Plants are more susceptible to *Kaphaja* diseases in winter and spring.

Symptoms

Deformity of leaves, slow maturing of fruits and less taste in fruits are the general symptoms of *Kaphaja* diseases.

Treatment

Kaphaja diseases must be pacified with decoctions that are pungent and hot in nature. The decoction of the group of five roots (*Brihat Panchamoola*) and water mixed with Surabhi (a fermented preparation) is indicated in the ancient texts.

- A paste of sugar and mustard is applied at the root and then the plant is irrigated with water mixed with the ashes of Sesamum sp.
- The mud and soil around the plant affected by *Kaphaja* diseases is removed and replaced with dry and hard soil.
- Tree could be nurtured with tepid water.
- An infusion prepared from barks of Plaksha *(Ficus arnothana)*, Pilklan, Udumbara and Saptaparna or Biton bark *(Alstonia scholaris)*, Neem *(Azadirachta indica)*, Sweet flag, nut grass and Rohitaka is prescribed.
- Watering for seven days with decoction of Vyaghri *(Solanum xanthocarpum)*, Sahacara *(Barleria prionitis)*, Neem, Sweet flag, Kadhira *(Acacia catechu)*, Black catechu and Rohisa-Roosa grass *(Cymbopogon schoenanthus)* is recommended.

The roots of affected trees should be dressed with oil cake of Siddhartha or White mustard *(Brassica juncea)* and irrigated with water in which Tila, Sesamum and ashes are dissolved.

Rationale

The line of treatment of *Kaphaja* disorders is the use of substances possessing pungent, bitter and astringent taste. Use of fermented preparation such as Madya is also indicated. *Panchamoola* possesses these qualities and is specifically used in *Kapha* and *Vaatha* disorders. *Nimba (Azadirachta indica)* and *Saptaparna* are mentioned in Sushrutha for treatment of Kaphaja diseases.

Exogenous Diseases

Vrkshayurveda also discusses the treatment of a large number of exogenous diseases and their management. These diseases are of several kinds, such as those caused due to worm infestation, insect attack, trees affected by fire, hail, storm, cold winds, dried trees, cut and broken branches, trees struck by lightning, etc. Although we are not going into this in detail here, this is a subject of great importance in terms of its significance in controlling crop pests.

Farmers' Practices for Pest Control

Prior to the introduction of chemical pesticides, farmers used a wide range of traditional pest control practices. These practices are rapidly disappearing as farmers adopt high-yielding varieties which necessitate chemical use. Pest control practices can be categorised as botanical, mechanical, agronomical, biological and other methods. In addition, some practices are supplemented with religious ceremonies and rituals. Our farmers have adopted various innovative techniques from time immemorial for the cultivation of crops. These methods were simple, cost effective, eco-friendly and easily adaptable.

Botanical Methods

Our farmers possess a wide knowledge of the botanical species in their environment and have identified a wide range of plants they could use for pest control. In this section we have listed some farmers' practices and their rationale based on the Ayurvedic view point.

1. The leaves of Karanja *(Pongamia pinnata)* and *Crotalaria retusa* are added to the soil to control pests.

Rationale

Pongamia sp., (which is included in Sushrutha), reduces Kapha and is also anti-helminthic. It is pungent in taste.

2. To control rats, pieces of raw papaya are spread in the field. Farmers have observed how raw papaya causes tissue damage in the mouth of rats.

Rationale

Raw papaya *(Carica papaya)* is extremely heaty and is used as an abortifacient in folk medicine.

3. Use of *Calotropis*

Green leaves of Arka *(Calotropis gigantea)* are spread on fields which are infested by larvae. The larvae settle down under the leaves

during the night and in the morning can can be collected and destroyed by burning. Fresh leaves are placed every day. Farmers divert the harvested rain water of adjoining fields into the weed-affected fields. Cut branches of *Calotropis* sp. are kept at the entrance of the rain water channel. This practice minimizes weed population to a great extent if repeated several times during rainy days. For control of aphid in lucerne *(Medicago sativa)*, farmers place freshly cut branches of *Catotropis* in irrigation channels. *Calotropis* plant material (8-10 kg) is soaked in water for about 24 hours and filtered. This liquid is poured on termite infested soil. The effectiveness is evaluated by placing pieces of wood at various points in the field. If the wood is not affected for one week then the treatment is considered effective.

Rationale

Calotropis is included in Sushrutha and Charaka. It reduces *Kapha* and *Vaatha* dosha, is bitter in taste, anti-helminthic and anti-toxic.

4. Use of Castor Oil to Prevent Shedding of Bloom

Flowers and young balls are often shed in cotton crops due to high temperature. To minimize this problem castor oil (approximately 50 ml) is poured near the stem in the soil to cool the soil. This is an age-old practice.

Rationale

Castor oil spreads and permeates through the body quickly and can retain its property for a very long period. The bloom or young balls of cotton tend to fall in the presence of *Ama dosha* (metabolic waste). This is effectively dealt with by castor oil which encourages growth of the plant. For burning sensation in the eyes, castor oil is used as an eye drop to bring about a cooling effect.

5. Use of Oil Seed Cakes

The oil seed cakes of Eranda or Castor *(Ricinus communis)*, Nimba Sarshapa or Mustard *(Brassica compestris)* and ground nut-Mandapi *(Arachis hypogaea)* when incorporated into the soil have been found to be highly satisfactory in controlling plant parasitic nematodes. They remain effective for over six months in the soil.

Rationale

Oil seed cakes are considered dry i.e. devoid of water or oil content and hot in potency which is diametrically opposite to that of the internal environment which harbours worms and parasites. So all substances which are pungent, bitter or astringent in taste and are dry, act quickly, are hot and light, would be effective in the management of pests.

• *How important is the analysis of these practices by farmers and the understanding of their rationale in Ayurvedic terms?*

From our experience we feel that it serves a very important purpose. Such an analysis lets us extend the scope and application of farmers' practices. For example, once we know that a treatment is effective because it regulates Vaatha, it opens up the possibility of modifying, extending or enhancing the efficacy of treatment by trying out other substances or regimens that can regulate Vaatha. We can also evolve treatments based on the properties of materials known from Vrkshayurveda to new conditions or situations not described or dealt with by Vrkshayurveda.

• *Are the prescriptions of Vrkshayurveda exotic and expensive?*

At first glance, a reader may wonder if the prescriptions of Vrkshayurveda are exorbitant. The frequent mention of ingredients like honey, ghee and milk may also make one wonder if these are practical. We can, however, assure the reader that there are indeed a large number of recipes that are easy to put to practical use. Even in cases where relatively expensive ingredients are specified, they are often in quantities that make the effort entirely worthwhile.

Here is the response of K.K. Somani published in "Jeevaniya":

"I had some trees of 'Sitaphal' (custard apple) at our Nashik farm which were not yielding any fruit for 15 years. The fruit would form but would drop off only after a small growth and this was in spite of using fertilizers and full irrigation.

"After reading Vrkshayurveda, I applied about 1 kg milk together with various pulses, ghee and honey, all together costing less than Rs.50 only once in the last winter in 1994. Within three months, I got a record crop of Sitaphals which were also extremely delicious.

"In the second instance, I had ordered some small plants of fruit trees from Delhi for plantation at Nashik. Out of 20 plants, about four plants (3 to 4 days after reaching Nashik) started drying and dying. I immediately applied on the entire plant the above mix of milk, honey and ghee with various pulses and re-planted the same. Not only did the small plants come alive again in just 15 days but started growing with new leaves without further damage. The cost of this treatment was less than Rs.10 per plant. It can be seen therefore that the cost of treatment is not high nor is it irrelevant today in spite of all the progress of our so-called science.

"I am sure that the various diseases of plants which are treated by pesticides can be more conveniently and less expensively treated with what has been suggested in Vrkshayurveda."

Conclusion

What we have outlined here is a very small fragment of one or two themes from the vast expanse of the subject matter that is Vrkshayurveda. Vrkshayurveda today is assuming great importance, particularly in agriculture where there is a global effort seeking sustainable and non-chemical strategies for farming. In this area traditional knowledge and practices of farmers are already playing a key role. Neem, which is today a mega player in the global scene in natural farming, is based on the traditional knowledge of the Indian farmer.

We in India are in a particularly advantageous position in this respect. Not only do we have a wide base of folk knowledge and practices amongst our farmers, but we also have a corpus of rich textual knowledge based on strong theoretical foundations in terms of the literature in Vrkshayurveda. In fact the available printed literature on the subject is only a very small portion of this material. An enormous wealth of information still awaits study in the form of manuscripts that are as yet unpublished. A preliminary examination of the New Catalogus Catalogorum of the Madras University (which is a list of all Sanskrit manuscripts in public collections the world over) reveals that there are hundreds of unpublished manuscripts on this subject in Sanskrit. A systematic analysis of the published literature and the manuscripts on this subject is bound to be a very valuable addition to our knowledge of plants. It is also certain to make substantial contributions by suggesting new lines of treatment for important problems such as non-chemical approaches to agriculture, particularly with respect to pest control and crop protection.

Notes on Commercially Available Biological Control Agents

By T.M. Manjunath and G. Sugathan

Biological control is the method of controlling pests by making use of their natural enemies (i.e., parasitoids, predators and pathogens) which are purely beneficial.

Ready availability of the required quantities of healthy natural enemies for timely releases is an essential prerequisite for undertaking practical biological control. This calls for establishment of insectaries. Countries like the U.S.A., the U.S.S.R. and China have taken the lead in establishing such insectaries where mass-production of parasitoids and predators is undertaken. It is reported that there are some 40 commercial insectaries in the U.S.A., about 7 regional laboratories in the U.S.S.R. and a number of production units in China which annually produce millions of parasitoids and predators for control of a variety of pests. In India, a beginning has been made by Pest Control (India) Ltd. by establishing "Biocontrol Research Laboratories" (BCRL) at Bangalore in June, 1981 (Ridgway and Vinson, 1977; Dietrick, 1981; Manjunath, 1984).

Biocontrol Research Laboratories (BCRL) is the first and only commercial insectary in India. The activities of BCRL include identifying promising natural enemies of key pests; developing economic mass-production, packing arid release techniques; supplying required natural expertise; and to popularise biological control as a practical method of pest control. Unless the farmers are assured of a dependable source of natural enemies, they cannot be expected to practice biological control. BCRL is trying to fulfill this need as far as possible. Now, a number of farmers from different parts of the country have been relying on parasitoids and predators that are being produced in our insectary for control of sugarcane bores, cotton bollworms, coconut black-headed caterpillar, mealybugs, scale insects, etc. For the benefit of farmers and other readers, brief notes are given on some of these natural enemies.

Notes on biological control agents.

Trichogramma parasitoids to Control Sugarcane Borers, Cotton Bollworms, Apple Codling Moth, etc.

Trichogramma species are amongst the most important and widely used parasitoids for control of variety of lepidopterous pests throughout the world. In India, different species of Trichogramma are available for control of sugarcane borers (i.e., early shoot-borer, internode-borer, stalk-borer, top-borer, etc.); cotton bollworms (i.e., spotted

bollworms, pink bollworm, *Heliothis armigera*); apple codling moth, etc.

Trichogramma is an egg-parasitoid. The tiny adult parasitoids which remain active in fields, locate the host eggs and parasitise them, i.e., the parasitoid lays its own eggs within the eggs of the pest. On hatching, the parasitoid larva feeds on the host egg and completes its development within. The parasitised eggs turn black, an invaluable diagnostic character, in 3 to 4 days and adult parasitoids emerge in 7 to 9 days. Thus, instead of the pest larvae hatching from the eggs, the parasitoids come out. A single parasitoid can thus destroy over 100 eggs of the pest.

Trichogramma kills the pest in the egg stage itself before the pest could cause any damage to the crop. It is a purely beneficial insect.

Releases of 40,000 to 1,00,000 parasitoids/acre are recommended. The parasitoids are supplied by BCRL in the form of "Tricho Card". Each "Tricho Card" carries 20,000 *Trichogramma* parasitoids.

Parasitoids To Combat Coconut Black-headed Caterpillar

The coconut black-headed caterpillar is a serious pest of coconut palms. The caterpillars feed on green portions on the underside of leaves, mostly on lower fronds. They remain concealed in galleries formed of silken webs and excreta. Severely affected fronds dry up, weakening the palm and reducing the yield.

Two larval parasitoids, namely *Goniozus (=Parasierola) nephantidis* and *Bracon brevicornis*, have been found to be promising for controlling coconut black-headed caterpillar.

When the parasitoids are released in the field, they go in search of the caterpillars feeding on coconut leaves. On locating a caterpillar, the parasitoid paralyses it by stinging and lays up to 12 eggs on it. The eggs hatch in 1 or 2 days. The parasitoid larvae feed on the paralysed host and complete their development in 3-4 days. They form cocoons on or near the remains of the host. After 7 to 10 days, adult parasitoids emerge and go in search of fresh caterpillars. A female can lay up to 120 eggs and these are distributed on several caterpillars. Thus, the caterpillars are killed while the parasitoids multiply themselves. Releases of 1,200 to 1,800 parasitoids/acre/season are recommended.

Ladybird Beetles to Devour Mealybugs and Scale Insects

Mealybugs and scale insects are serious pests of a number of agricultural and horticultural crops. These insects which hardly move,

build up thick colonies on leaves, stem, fruits, etc. and suck the sap from the plants. Besides such direct damage, these pests secrete a sticky substance known as "honey dew" on which "sooty mould" fungus develops; consequently, the infested surface becomes black. Heavily infested parts shrivel and drop or become so sticky and unsightly as to render them unfit for marketing or consumption.

Three species of ladybird beetles, namely *Cryptolaemus montrouieri, Symnus coccivora* and *Nephus* sp., can give effective control of mealybugs infesting coffee, citrus, grapevine, mango, etc.

Similarly two other species of ladybird beetles, *Chilocorus nigritus* and *Pharoscymnus horni*, destroy scale insects damaging sugarcane, coffee, sapota and several other crops.

The adult ladybird beetles, being winged, search for mealybugs or scale insects and feed on them throughout their life. They live for about 45 days. They lay their tiny eggs in the colony of the pest. Each female can lay 100 to 250 eggs or more depending upon the species. Eggs hatch in 5 to 6 days and the grubs voraciously feed on all stages of the mealybugs or scale insects. They are particularly fond of eggs sacs and gravid females, and often completely wipe out the pest colonies. They then enter into the pupal stage, usually in groups, in the crevices of the bark, fallen dried leaves, in leaf folds, infested plant surface, etc. The pupae do not move. Adult beetles emerge from the pupae in 8 to 10 days. They mate and again start feeding and breathing. Thus, the ladybird beetles destroy the pest while building up their own populations.

A minimum release of 600 ladybird beetles/acre is recommended. The releases are to be made at the first sign of the infestation.

Parasitoids To Control Citrus/Coffee Mealybug:

An exotic parasitoid, namely, *Leptomastix dactylopii,* has given good results in controlling the citrus mealybug, *Planococculs citri.* It is a specific parasitoid of this species.

This Encyrtid parasitoid actively searches for mealybugs in fields and lays its eggs in the mealybug. On hatching, the parasitoid larva feeds and develops on the mealybug. It completes its development in 16 to 18 days and emerges as adult. The adult parasitoid can live for 30 to 40 days, and each female can lay up to 200 eggs. A minimum release of 2,000 parasitoids/acre/season is recommended.

Parasitoids To Control Housefly And Other Filth Flies

The pupal parasitoids, namely *Spalangia* spp., *Dirhinus* spp. and *pachycrepoideus vindmmiae*, have been found to be promising and are

being mass-multiplied. These parasitoids, if released in sufficient numbers, can play an important role in suppressing fly populations in poultries, dairies, piggeries, dumping yards, etc. where the housefly and other filth flies breed profusely.

The parasitoid of filth flies live within the manure, never becoming pests themselves. The female parasitoids are ready to mate and oviposit immediately after emergence from their hosts. The parasitoid lays its eggs within the fly puparia. The eggs hatch and the parasitoid larvae develop by consuming the fly puparia. Finally, the fly puparia are destroyed as the parasitoids complete their development. It completes its development from egg to adult emergence in 15-18 days. A single female parasitoid lays its eggs in about 100 puparia in about 15 days, thus causing their death as they multiply themselves.

Methods of Supply and Releases

Suitable methods have been developed to pack different states (i.e., eggs, larvae, pupae and adults) of the parasitoids and predators and send them to distant places by airfreight/Speed Post/Courier Service/Parcel/Post, etc. depending upon the convenience.

The methods of releasing biological control agents are generally simple. The adult parasitoids or predators can be distributed in the field by holding the containers open and walking all over the field. Being winged, they escape and start searching for their respective hosts in the field. The immature stages like eggs, larvae or pupae of the natural enemies are to be distributed in the field by placing them on or in the vicinity of their hosts. Detailed guidance for releasing and handling the natural enemies are available.

Advantages of biological control

1. The parasitoids and predators have the natural ability to search for their hosts and attack them.

2. The natural enemies are capable of self-dispersing and self-propagating so that control is obtained over an entire area and it continues indefinitely. Thus, it will have far-reaching cumulative benefits.

3. No upsets in the balance of nature or resurgence of pests are caused since the biological control agents fit into the ecosystem without disrupting any other components.

4. Parasitoids and predators employed in biological control are purely beneficial. There is no danger whatsoever of the parasitoid or predator itself becoming a pest.

5. Biological control is manipulatable, augmentable and compatible

with enlightened integrated control programmes wherein restricted use of chemicals combined with cultural and other ecological methods are employed.

6. Problems such as toxic hazards, residues, environmental pollution, destruction of non-target beneficial organisms, etc. that are commonly associated with chemical control measures, are not encountered in biological control. Hence, it is safe.

Although the concept of biological control is not new, it needs to be popularised amongst the farmers. They must be made to understand that biological control is economical, effective and ecologically sound.

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Spiders in the Paddy Ecosystem and their Conservation

By K. Vijayalakshmi and N. Raja

Introduction

People get repulsed by spiders. Or recoil from the sight of them. But the spiders of our country do not deserve such a hostile response. Spiders are as harmless, beneficial, colourful, predatory and lovable as any of the other living creatures on the earth.

The main reason why people kill spiders they spot is the ugly looking web, which spiders construct for many purposes like catching their prey, attracting the opposite sex, etc. But the fact is that all spiders do not construct webs. There are certain spiders called "wanderers" which do not construct webs to catch their prey but actively chase their prey to feed on them. They are beneficial to human beings in the sense that they feed on the pests of crops. Predatory arachnids such as spiders are an important group of biological control agents. They are able to survive periods of starvation when prey is difficult to find. As the use of chemical insecticides gained currency the role of spiders as natural pest controllers was greatly neglected and even forgotten.

Spiders generally use their well developed sense of touch to find their food. They are carnivorous and feed only on living creatures especially other arthropods which they first subdue with their poison. Normally, a spider injects digestive juices into its prey's tissues and then sucks out the resultant broth. Web spinning spiders trap their prey in a silken trap called a web while the hunters chase and pounce upon their prey to make a kill. Both these groups of spiders are important in an agroecosystem to keep pests under control. We shall now take a look at some important spiders of the paddy ecosystem.

Family: Araenidae

Spiders belonging to the genus *Argiope* are found with their webs in plenty during the earhead stage. These spider species build an almost vertical web with the hub and a vertical stabilimentum consisting of a zig-zag band of white silk. The spiders hang head downwards in the hub day and night. These spiders are quite large. Because of their large size they are one of the important predators. However these species occurs in low population densities in the rice ecosystem.

They make circular webs in rice fields capturing mainly grasshoppers and moths as their prey. They have also been observed to feed on leaf and plant hoppers. Grass land forms one of the habitat of these spiders. In the grassland also these spiders capture diverse species of insects like grasshopper and leaf hoppers and other insects that migrate from the rice field. It is important to realize that natural control of pest insects by spiders not only takes place in the rice fields but also in the adjacent grassland and other neighbouring habitats. *Argiope*'s role may consist of suppressing pest insects before they invade paddy. In using these species as biocontrol agents one could also think of creating suitable habitats adjacent to the paddy fields for increasing their numbers. During the time when the earheads are ripe and ready for harvest their numbers decrease.

Family : Tetragnathidae (Long Jawed Spiders)

These spiders have long legs and bodies. They prefer to live near a water source. They build webs with fewer spokes. They cling to the leaf blades with the third pair of legs and other pairs stretched backward and forward along the leaf blade. Their webs are ring shaped and weak.

Family : Lycosidae (Wolf Spiders)

Members of genus *Lycosa* are found in plenty. These are hunting spiders living in burrows in the ground. These spiders are found along with the egg sac attached to spinnerets. In this group females carry the young ones on their back after hatching. They are observed to feed on stem borer moths, plant hoppers and leaf hoppers. They are normally found among tillers at the base of plants. Since they do not construct webs they directly attack the prey.

Family Oxyopidae (Lynx spiders)

Spiders belonging to both the genus *Oxyopes* and *Peucetia* are found in abundance in irrigated paddy. Several females with eggsacs are found during earhead stage before harvest and also after harvest. At the time of harvest they are found with eggsac. These are hunter spiders and do not build webs. They live for three to five months within the rice canopy. They also feed on plant and leaf hoppers and moths.

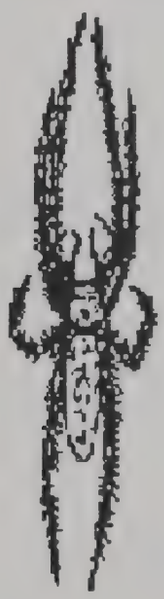
Family : Salticidae (Jumping Spiders)

Salticidae is another group of hunting spiders popularly known as jumping spiders. They have well developed eyesight and hunt

Orb Weaver

Lynx Spider

Wolf Spider



Long Jawed Spider

their prey. This family is characterized by a massive square head. Salticids are usually found to retreat into their silken nests where they also moult or lay their eggs for safety. *Phidippus* species are found in the paddy ecosystem. They have been observed to prey on green leaf hoppers. Their egg masses are elongated.

Conservation of Natural Spider Fauna

The extent to which spider control is realized in an agroecosystem is limited by factors such as application of pesticides, annual harvesting and tilling of the vegetative ground layer. All these factors contribute to the mortality of spider populations. Though spiders are less sensitive to insecticides than other predators, agricultural practices tend to suppress spider diversity and density in these systems. If we have to obtain maximum control effect from spiders then we have to take measures to maintain spiders community

diversity in the paddy ecosystem. What are the measures that we could take?

Cultivation

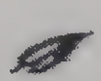
Planting and harvesting procedures are very disruptive of spider communities: both the habitat and beneficial fauna are destroyed. Recolonization by large scale population of agricultural systems is possible with respect to that portion of the spider that balloons (disperses on silk threads caught by air currents). The major ballooning spider families are the small sheet-like weavers (Linyphiidae) the wolf spiders (Lycosidae) and Orb weavers (Araenidae). One of the reasons why the Chinese and Japanese have been successful in using spiders for biological control in rice paddies is that the ballooning linyphiids are the major predators of the leaf hopper-planthopper pests of that system. Suitable hedgeplants in adjacent areas could also be thought of. These could serve as natural reservoirs of spiders. The Chinese actually use straw bundles to provide shelter for spiders. These bundles are initially laid down in areas where spiders are numerous and are subsequently transported from field to field as needed to implement control. This practice has reduced the level of chemicals required to control various insect pests by between 50 and 60 per cent.

Augmentation

By introducing eggsacs into the fields theoretically it might be possible to augment the predatory effect of spiders. To do this one would have to circumvent spiders inherent antagonistic behaviour. Territory size i.e. personal space is under some genetic influence. It is conceivable that artificial selection for tolerance towards conspecifics can be accomplished for some of the more prominent agroecosystem spider species like *Oxyopes*.

Remarks

The spider community as a whole can effect better control over pest populations than any individual taxon. Long term experimental studies on the effect of spider communities on prey population are needed. We need to also understand the rates of recolonisation of areas following disturbance.



Section V

Economic and Social Aspects of Organic Farming

Section editor: Korah Mathen

This final section deals with aspects relating to organic farming that are perhaps of as great significance as the earthworm and soil microbe: the comparative economic and productivity analysis of organic and conventional farms.

Surprisingly, there is not much information available on this important aspect of organic farming. Most of the data available relate to conventional farms which have a well-organised system of recording data largely designed to prove the system of farming as the best and most productive. Data about traditional farming systems is hardly available in commensurate quantity though the majority of the world's population of farmers are traditional, subsistence based food-growers. Data about modern organic farms is only now being collected in a significant way, even by policy makers.

The Greenpeace report on organic farming is the first major study of the productivity of organic versus conventional farms. We have included here only the chapter that describes organic types of agriculture and which summarises the results of comparative studies. The results are quite revealing. Since the survey is quite systematic, its results have to be taken seriously.

The second essay is taken from a much discussed report on alternative agriculture in the United States. The full study documents the gain in income at organic farms in view of the obvious decline in use of expensive chemical inputs. Productivity gains are also quite impressive.

One of the routine arguments used against organic farming is that it is not as productive as conventional farming. If one enters the debate, one is sure to get stuck at the definition of "productivity". Caution is necessary when dealing with definitions. Words may be

defined in such a way as to further the debate in one direction alone and to scuttle other options. Vandana Shiva critically analyses the idea of productivity on conventional farms, and argues that the polycultures associated with traditional farms produce a richer harvest taken together when compared with the single-crop yields typically associated with conventional farms.

In my own piece, I have critically dealt at length with the idea of productivity being propagated by conventional agricultural scientists and experts and show how these would not stand up to elementary scrutiny. The sooner we get rid of such primitive methods of cost-calculation and economic benefit, the better for all concerned since it will enable us to make wiser investment decisions and exercise better political choice when it comes to selecting the best farming system that this planet can live with on a sustainable basis.

Organic and Conventional Agriculture Compared

By Greenpeace (Europe)

Among the alternative farming methods in Europe, organic agriculture is the best known. Organic farmers practise a diversity of methods, producing environmental improvements ranging from moderate to excellent.

A comparison of organic with industrial farming reveals that organic agriculture is significantly better for the environment than its industrial counterpart. Case studies show improvements in a wide range of factors, including, for example, nutrient leaching, pesticide pollution, energy use, and diversity of wildlife. Studies also show that organic types of agriculture are technically and economically viable, and that they can produce sufficient food to meet Europe's needs.

This chapter briefly describes organic types of agriculture, and summarises the results of comparative studies.

What is Organic Agriculture?

There are various government definitions of organic agriculture. The US Department of Agriculture's definition is: "A production system which avoids or largely excludes the use of synthetically compounded fertilisers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely on crop rotations, residues, animal manures, legumes, green manures, off-farm organic wastes, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests. The concept of the soil as a living system...that develops...the activities of beneficial organisms...is central to this definition." (*US Department Agriculture 1980*).

Organic agriculture covers a wide range of practices, and it is not homogeneous. Organic methods work with natural biological processes and rely primarily on farm-derived, renewable resources, rather than external inputs such as pesticides and fertilisers. Farmers and researchers around the EC and in many other countries have developed different techniques, ranging from traditional regional practices to biodynamic farming and permaculture. But there are strong unifying principles in the organic approach. Organic farmers see the soil as a living medium that has to be nurtured. They value it as a source and store of nutrients for crops, as a habitat for organisms that recycle nutrients by digesting waste material and as a habitat for antagonists of pests and diseases. The interaction

between minerals, water, humus and air, and the living organisms in the soil is seen as the essential basis of a healthy production system (Balfour 1943; Bourguignon 1989).

Organic Agriculture on the Increase

Organic farmers tend to view the agro-ecosystem as a whole. They are aware that their actions in one sphere can affect other parts of the ecosystem for better or for worse. They take advantage of the cycles and interaction between animals, plants, soil and climate that are fundamental to enhancing the ecosystem's productivity and efficiency. Organic agriculture attempts to work with natural cycles rather than disrupting them (Lampkin 1990). In contrast, industrial agriculture relies on external inputs, which disrupt key biological systems. Thus organic nitrogen fixation is replaced by nitrogen fertilisers, beneficial insects and earthworms are destroyed by pesticides, and animal immune systems are disrupted by the routine use of antibiotics (*Howard 1975; Vogtmann 1985; Altieri 1983; Koepf, Petterson and Schaumann 1980; Vereijken 1986*).

Organic farmers do not simply substitute "organic" inputs for agrochemical ones. They generally avoid using pesticides. In severe cases of pest attacks, as an emergency measure, organic farmers are allowed to use a small number of pesticides that are thought to be non-persistent. Organic agriculture appears to be based on "old-fashioned" mixed farming practices, but organic farmers in fact use new ecological methods as well as selected traditional techniques.

Comparison of Environmental Effects of Organic and Conventional Agriculture

Reduced Nutrient Leaching

The difference between organic and industrial farming practices leads to significantly different levels of nutrient pollution. On organic farms, arable and animal husbandry are generally integrated, and livestock numbers are often limited to one "animal unit" per hectare. Farmers are not allowed to use artificial fertilisers. Instead, the organic farm structure encourages farmers to use animal manure as effectively as possible, and to employ techniques that enhance plant uptake of nutrients and minimise losses of nutrients to the surrounding environment. Planting nitrogen fixing crops is one of the organic farmer's options to achieve this. The possibilities for improved nutrient management within organic systems mean that a much smaller proportion of nutrients leach from the system to contaminate the environment. The following studies compare the differences bet-

ween organic and conventional systems:

- A Danish study compared the loss of nitrogen over two years from 14 organic and 16 conventional dairy farms (Kristensen and Kristensen 1992). It concluded that the nitrogen surplus (potential loss to the environment) on the conventional farms was, on average, 240 kg per hectare whereas on organic farms it was 124 kg per hectare—half per hectare—half as much. The use of nitrogen was 25% more efficient on average on the organic farms. A nitrogen surplus was recorded for every field on the conventional farms, with a minimum surplus of 58 kg nitrogen per hectare. In contrast, the organic farms had many fields with no nitrogen surplus. If the results of this study are extrapolated to the whole of Denmark, we find that the conversion of cattle farms to organic methods would probably spare the environment about 111,000 tonnes of nitrogen pollution per year.

  The organic farms in the study seldom exceeded 1.5 animal units per hectare. This is because the Danish rules for organic farming state that the majority of the fodder must be produced on the farm itself. This allows for a balance between the number of animals and the area of the organic farm. By comparison, there are no limits on purchased animal feed in the conventional farm structure and thus no limits to the amount of imported nutrients.

  The difference in number of animals, however, is not in itself sufficient to account for the difference in the nitrogen surplus. When the number of animals per hectare was adjusted to make it equal for both farming practices, the potential loss to the environment was still considerably less in the organic system—85 kg nitrogen per hectare per year. It is the large nitrogen inputs in the form of synthetic fertilisers and imported, pre-mixed animal feed that causes the excessive burden of nitrogen in conventional farming.

- Another study in Denmark compared the nitrogen balances of 13 organic and 13 conventional cattle farms (Kristensen 1991). The calculated nitrogen loss per hectare on the organic farms was 75% less than on conventional farms. This difference was partly accounted for by the fact that the conventional farms had more livestock than the organic farms. When the nitrogen loss was calculated per animal unit, the organic farms were still found to lose 40% less nitrogen than the conventional.

- A German study measured the nitrate content of leached water under organic and conventional fields. The average from 15 organic fields was 27 milligrams nitrate per litre (a range of 10-51 mg. nitrate per litre). Conventional farms with animals had an average of 79 mg nitrate per litre in leached water; for farms

without animals the figure was 42 mg. nitrate per litre. So the average organic farm was significantly better than the average conventional farm. The study showed that improved nutrient control systems like Integrated Nutrient Management on conventional farms could cut nutrient losses to 30 mg. nitrate per litre in leached water. However, this "best practice" on conventional farms still failed to bring nitrate levels under the EC recommended target for drinking water (23 mg nitrate per litre). The best organic farms had much better values—only 10 mg. nitrate per litre (Brandhuber and Hege 1992).

Reduced Energy Inputs

Organic agriculture offers significant opportunities to reduce fossil fuel consumption compared to industrial agriculture. It has been estimated that a conversion to organic agriculture can reduce energy consumption by approximately 50% (Joint Committee for Ecological and Biodynamic Farming 1991). Other studies suggest that the energy consumption could be reduced further (Jenkins 1990).

Chemical fertilisers require large amounts of energy to manufacture, and are one of the most energy intensive inputs of industrial agriculture. Studies show that organic agriculture uses much less fossil fuel energy because it relies on biological rather than industrial nitrogen sources, it recycles nutrients in manures and crop residues, and it uses farm-produced forage instead of purchased animal feed. For example:

- Studies of organic versus conventional farming compiled by Lampkin (1990) suggest that organic farms in Britain use between 25% and 100% of the energy per hectare used by conventional farms. Organic farms in the UK use 20% of the energy used to produce conventional wheat in Germany; they use 50% of the energy used for conventional wheat in France; 42-85% of the energy for conventional cereals in the US; and 50-90% of the energy used for all conventional crops in the US.
- Lockeretz et al (1977) compared 14 organic farms (in the US corn belt) with conventional neighbours. Even though both sets of farms had very similar economic returns, the conventional farms used 2.3 times more energy than the organic farms per dollar of farm output. On the basis of these figures, Jenkins (1990) calculated that the ratios of direct energy input to output were about 1:3 for industrial agriculture, approximately 1:5 for mechanised organic farms, and approximately 1:11 for manual organic agriculture.
- Pimentel estimates that 25 wet tonnes of dairy manure (containing nitrogen, phosphorus and potassium) requires 375,000 kcal of

energy per hectare if transported 3 km. to the fields and spread. The energy consumed by applying chemical fertilisers to the fields is 1,913,319 kcal/hectare, or over five times as much energy (Pimentel et al. 1984). Organic nutrient methods can therefore save more than 80% of the energy consumed by synthetic fertilisers.

- Energy savings from not using pesticides have been calculated for the US. In the midwest corn-cropping systems, substitution of 7.9 kg of herbicides with two additional cultivations led to an overall energy saving of over 700,000 kcal/hectare, despite the extra fuel used for the cultivations. Five additional cultivations in potatoes, as a substitute for 18 kg/hectare of herbicides, resulted in energy savings of more than 1,300,000 kcal/hectare (Pimentel et al. 1984).

Increased Biological Diversity

Organic agriculture can play a very positive role in maintaining biological diversity in agricultural systems and in wildlife habitats. The mixed livestock and arable system used by many organic farms (which takes advantage of the beneficial relationships between animals, plants, soil and climate) enables farmers to maintain many of the cyclical processes characteristic of natural ecosystems. A wide range of crops and animals creates a physically and biologically diverse ecosystem. For example:

- Various studies show that there is a greater abundance and diversity of wildlife in organically managed arable crops than in conventional ones (Ingrisch, Wasner and Glück 1989; Wolf-Straub 1987; Zwingel 1987; Frieben 1988; Ries 1988; Plakolm 1989; Elsen 1989).
- Undersowing of crops (such as a grass/clover mix undersown in cereals) is an important feature of many organic agriculture systems. This practice has been shown to support a higher diversity of insect species and to minimise nutrient leaching. The effect of undersowing can spread beyond the edges of the field in question (Vickermann 1978), resulting in significant increases in the variety of insects over the whole farm. These, together with the more varied habitats that result from a mixed rotation, are likely to encourage bird populations on organic farms.
- In Denmark, a comparison of conventional and organic farms by the Ministry of the Environment (Braae et al. 1988) revealed significantly higher numbers of birds, notably skylarks, grey buntings, swallows, lapwings, and linnets, on organic farms.

Enhanced Soil Fertility and Structure

Organic agriculture methods aim to maintain or build up soil organisms and structure to feed crops and to create the right conditions for their roots. Important methods to achieve this include rotations with grass leys, green manures, after cropping, alley cropping, mixed or inter cropping, and undersowing of crops. Other important practices are the maintenance of plant cover, whether it be "weeds", green manures, crop residues or leys, all of which lessen the impact of rain on the soil and thus reduce the disintegration of soil particles. Organic manuring also plays a crucial role in the biological formation and stabilisation of the soil. Furthermore, there is considerable evidence that the techniques used by organic farmers can significantly reduce the risk of soil erosion.

- In 1980, the US Department of Agriculture concluded that organic methods are very consistent with those of well-established soil conservation measures (Arden-Clarke and Hodges 1987).
- In a comparison of soil on two neighbouring US wheat farms, one conventional and one organic, it was found that between 1948 and 1985 the conventional farm lost 21 cm of topsoil, one third of the initial topsoil present, and over four times the amount of topsoil lost on the organic farm, which was 5 cm. The organic farm soils had higher organic matter, cation exchange capacity, nitrogen and potassium, pH, enzyme levels and microbial biomass than the conventional farm (Reganold 1988).
- A study of one dairy farm that had been managed biodynamically since 1929 found only minor differences between 1972 and 1982 in phosphorus, potassium and magnesium content in the soil. After 50 years the potassium and phosphorus levels were still sufficient for good yields, in spite of the fact that the only purchased inputs were feed and straw for bedding (Kaffka and Koepf 1989).

Reduced Pesticide Pollution

In organic agriculture, the use of chemical pesticides (including insecticides, herbicides and fungicides) is generally rejected. Practical experience on the farm shows that organic farmers do not generally experience significant pest problems, contradicting the critics who suggest that organic methods are impractical.

- In the US, 41% of all insecticides are used on corn. Eighty per cent of these are used to treat a pest that could be controlled simply by rotating the corn for one year with any other crop (Barse 1990; Pimentel et al. 1991).
- Organic farmers use almost none of the 600 or so pesticides per-

mitted in the Member States of the EC. As a result, there is a very clear difference in the environmental effects of organic and conventional farms: conventional farms cause enormous contamination of the environment with persistent, bioaccumulative or toxic residues. Each year, approximately 314,000 tonnes of pesticide active ingredients are put into the environment by conventional European agriculture (RIVM/RIZA 1991), compared to almost none from organic agriculture.

- Earthworms enhance soils by increasing the rate of crop residue breakdown into the soil, stabilising the soil surface, improving soil structure and increasing the infiltration rates of rainwater, thus reducing erosion threats (Zachman and Linden 1989). But pesticides threaten earthworm populations. Pesticides such as benomyl, ethoprop, carbaryl and bendiocarb, applied at the recommended rates, have all been shown to reduce earthworm populations by 60 to 90%, with effects lasting at least 20 weeks (*Porter et al. 1990*).

Organic farmers use a wide range of husbandry practices to promote natural checks within the ecosystem, and to prevent weeds, pests and diseases from getting out of control. These effective alternatives to pesticides include rotating a variety of different crops—for example, deep and shallow rooting, nitrogen fixing and nitrogen demanding—from field to field in a planned sequence over a period of years. This minimises nutrient losses as well as problems with pests and diseases. Other methods include encouraging natural predator control, using inherently resistant varieties, and increasing biodiversity. The emphasis is on a preventative approach rather than on the development of "cures", which too often create new problems.

Weeds can be tackled through husbandry practices such as rotations, choosing weed suppressive crop varieties, mulches, green manures, animal grazing, appropriate cultivation before the crop is established, and by hand, machine or flame weeding. The aim is not to eliminate weeds and pests completely, but to prevent them reaching damaging levels. Organic farmers are also aware of the benefits of allowing some weeds to grow: weeds can accumulate minerals from deeper levels, since they are often deep-rooting, and recycle them for use by crops; they can indicate micronutrient deficiencies and other imbalances in the soil; they can act as trap crops for pests; and they can provide valuable nutrients or have medicinal value for some livestock.

An exception to the general rule is organic vegetable production, where a high level of (non-chemical) weed control may be required to facilitate mechanical harvesting and avoid crop contamination, such as nightshade seed in process peas. In addition, the intensive nature of the system, usually because of limited land, may lead to greater

pest and disease pressures. There is probably a need to reintegrate horticultural production back into agriculture to achieve ideal conditions (Lampkin 1992).

People who argue that organic pesticide practices can be just as harmful as conventional pesticide practices fail to understand organic agriculture's different approach to pest problems: the aim is to encourage natural checks and balances so that the need to use pesticides is eliminated. The preventative approach avoids the pest and pesticide problems that are created as an integral part of industrialised agriculture.

Comparison of Yields

Most comparative studies show that crop yields in organic agriculture are on average between 10 and 30% lower than in conventional systems (LEI 1990; BMELF 1990; Rude 1990; Böckenhoff et al. 1986; Vereijken 1986; Priebe 1990). However, organic yields vary considerably, according to techniques used; varieties chosen, region, and so on, just as conventional yields vary.

- The results of a study on 200 holdings in Baden-Württemberg, Germany, in 1983 demonstrate how much yields vary (Böckenhoff et al. 1986). In these trials, the range of yields was very wide.

  Further analysis showed that yields of the top 25% of organic crops were equivalent to or above the conventional average. In some cases organic yields approached the top yields obtained by conventional farms of similar size and type. Other work in Baden-Württemberg shows that there is a clear correlation between yields and soil type, with the differences between organic and conventional yields being significantly less on better soils.
- Studies of biodynamic farms in Germany in 1971-1974 found that the average yields of winter barley were slightly lower on biodynamic farms than on conventional farms: 4.05 tonnes/hectare compared to 4.22 t/ha. The average yields for spring wheat and main crop potatoes were the same. However, the yields for some biodynamic crops were higher. The average yield for winter wheat was 4.54 t/ha on biodynamic farms, compared to 4.09 t/ha on conventional farms. The average yield for oats was 3.90 t/ha on biodynamic farms, compared to 3.66 t/ha (MELU 1977).
- Steinmann (1983) in Switzerland compared yields of wheat, rye, maize, oats, barley and potatoes from organic farms to those from conventional farms. His results show a relatively small drop in yields in the organic systems.

- Vine and Bateman (1981) compared yields of winter wheat on ten organic and ten conventional farms in the UK. They found that organic yields varied from 3.0 to 5.8 tonnes/ha., while conventional yields varied from 4.6 to 5.7 tonnes/ha.
- Steinmann (1983) investigated milk yields (litre/cow and litre/forage hectare) and found that yields on organic farms were respectively 8% and 28% lower than on conventional farms (which were similar in type and size). This was due to the organic farms' greater dependency on homegrown forage (which produced a lower yield per cow) and lower stocking rates (producing a lower yield per hectare).
- A three-year study of 27 organic and 27 conventional dairy herds in Germany found significantly lower culling rates and significantly higher ages of culled cows for the organic herds. While conventional cows had higher annual milk yields, there was no difference in total milk yield over the life of the cows in organic and conventional herds—because organic cows yield milk for more years (Klenke 1989).
- In Denmark, research found that organic milk yields per cow are around 15% less than in conventional systems (Kristensen and Henneberg 1989).
- Stanhill (1990) evaluated published comparative studies of organic versus conventional milk yields, and found that more than half the studies reported higher yields on organic farms. Overall results of the 205 comparisons for 26 different crops, milk and eggs found the mean yield ratio between organic and conventional to be 0.91. This meant a drop in yield of approximately 9%.

When farms initially convert from industrial to organic methods, yields may fall significantly, because the biological processes that make organic agriculture systems work take time to become established. Nutrient deficiencies and weed problems can sometimes occur, unless appropriate methods are chosen to take account of the local conditions, including climate and soil type. However, low yields in the early stages of conversion should not be taken as a guide to potential yield in an established system. Established organic farms can be expected to give a significantly higher yield than their new counterparts.

- A follow-up on the 1983 study in Baden-Württemberg of 44 organic farms (Dabbert 1990) showed a link between increasing yields and length of time under organic management.

Comparisons of Financial Costs

Organic agriculture has been dismissed by some on the grounds of its apparent cost. However, some false assumptions have been made about the relative costs of organic and industrial food production methods. Conventional agricultural products do nor carry their full cost. Relatively cheaper market prices for conventionally farmed products are a result of government agricultural policies, and the premium prices charged for some organic products.

In the UK, premiums for organic food have been found, on average, to be in the range of 0 to 150% for vegetables, 35 to 100% for cereals, and 15 to 30% for livestock products (Redman 1991). The price of organic products is increased by factors such as: small-scale production, widely dispersed farm, separate packing facilities, more expensive recycled packaging, and the pricing policies of shops. Nevertheless, the significant price differences show a willingness on the part of some consumers to pay more for food that they perceive to be superior in quality, or produced in ways that are better for the environment.

The prices that organic and conventional farmers receive for their products can be much more similar than the price comparisons in shops suggest. A large proportion of the price difference is generated after the product has left the farm.

- A Danish study, for example, produced a breakdown of the price of organic wheat flour compared to conventional flour in Denmark. It found that both organic and conventional farmers received less than a fifth of the final purchase price, although the organically farmed wheat brought in more money per kg than the conventional. The final price of the organic flour was twice the level of the final conventional price. The area where the differential was most noticeable was in the final retail profit, which for conventional flour was 3-4%. For organic flour the markup was 25%. Significantly higher retailer profit margins were also identified as a major cause of higher prices for organic bread (Jörgensen, Nielsen and Kristensen 1991).
- Another Danish study analysed the price paid by consumers for organic and conventional milk. The difference in the payment received by organic and conventional farmers was magnified by higher distribution costs and a higher supermarket profit for organic milk. The cost of the packaging and processing in the dairy was the same for organic and conventional milk (Hansen 1991).

The subsidies for conventionally produced food currently limit the growth of organic agriculture to the size of the market that is willing and able to pay the higher consumer prices.

Reduced External Costs

Part of the reason that organic is more expensive than conventional produce is that organic farmers internalise some costs that are treated as externalities by industrial agriculture. Another is that part of the production costs of industrial products are absorbed by governments (and the CAP) and passed on to taxpayers; these include hidden subsidies, such as the storage and disposal of surpluses, and pollution 'clean-up' costs. This creates artificially low market prices for products of industrial agriculture.

- Berenschot (1989) calculated for the Netherlands that the price difference between organic and conventional food roughly equalled the environmental (hidden) costs of conventional agriculture.
- In the United States, it has been calculated that the total environmental and public health costs of pesticide use, alone, are about $3-4 billion a year—equivalent to almost $1 in externality costs for every $1 of pesticide sold in the country. Globally, pesticide externality costs are estimated to be as high as $100-200 billion a year, equivalent to $5-10 for every $1 of pesticides sold (IFPRI 1990).
- In the UK it has been estimated by the government that it will cost £450 million to take excess pesticides out of drinking water to meet the EC residue limit.

Conventional farmers have an incentive to control their own on-farm costs, but they have little incentive to take action to reduce off-farm environmental costs. Yet the price of off-farm costs is increasingly high. Some governments have realised, for example, that the off-farm costs of soil erosion are generally much greater than the costs of erosion to the farmer.

- The OECD reports a US study that has estimated that the external costs of soil erosion are of the order of $2-6 billion per year. This is almost ten times greater than the on-farm costs of soil productivity losses (OECD 1989).
- The off-site costs of soil erosion in the US have been estimated at up to $20 billion a year, with more than one third of this blamed on agriculture. US cropland loses at least 3 billion tonnes of topsoil every year, making agriculture the single largest non-point polluter. A comparison of the full economic performance of organic and conventional farmers in Pennsylvania found that organic practices cut production costs by 25%, eliminated inorganic fertiliser and pesticide use, reduced soil erosion by more than 50%, and increased yields after the (five-year) transition from conventional systems had been completed. However,

current US farm policy provides economic disincentives for farmers convening to organic systems, despite the overall economic benefits that would be gained (Faeth et al. 1991).

The external costs are paid and suffered by society as a whole, or borne by the environment. To a large extent agricultural policies provide few or no incentives to farmers to minimise these off-farm environmental impacts. EC agriculture policies, coupled with technological developments that shift farmers to ever higher "optimal" input levels, have actively driven farmers to specialise and intensify, and in some circumstances make it financially very difficult to farm organically.

Comparison of Profit Margins and Labour

Despite organic farmers' voluntary internalisation of costs, some farms can in some circumstances achieve the same profit margins as conventional farms, even within the present policy framework. This is especially true where a premium is available for organic products. In most cases there are financial benefits as well as disadvantages resulting from farming organically. In practice, the balance varies from farm to farm, and from region to region, making it difficult to generalise from one situation to another.

The slightly lower average yields in organic agriculture experienced by farmers in Europe are often compensated for by lower variable input costs. These represent one of the major differences between conventional and organic systems. On grain crops, for example, expenditure on fertilisers and sprays is much reduced (BMELF 1990).

- Steinmann (1983) in a study of 20 organic and 20 conventional farms found that the organic farms had a slightly lower income from agriculture but that their overall income was slightly higher than the conventional farms (see table 4.10 overleaf).
- Vine and Bateman (1981) studied the costs and returns for winter wheat for ten conventional and ten organic farms in the UK. Ignoring the price premiums for organic produce, the gross margins for organic farms varied from £242 to £585 per hectare, while the gross margins for conventional farms varied from £331 to £424 per hectare. The study also found that most organic farms made considerable cost savings because they did not purchase any fertilisers and pesticides.
- Data collected in 1987-1988 from 57 full-time farms in Germany showed that although output was 82% of that of comparable conventional farms, total costs were 77% of conventional, with the result that the farm incomes were very similar (BMELF

1989). Official data show that organic farms save considerable costs on chemical inputs. In 1989-1990 conventional farms typically spent more than four times more on fertiliser, pesticides and feedstuff than organic farms. The organic farms spent more on labour.

Differences in the costs of spreading manures and fertilisers are minimal, as not every course in the rotation receives manure or slurry. As far as livestock are concerned, organic farmers spend considerably less than conventional farmers on concentrates and forage, unless, of course, organically produced feed has to be purchased. Veterinary bills on organic farms (where the animals are less densely stocked and less stressed) tend also to be considerably lower.

Where both lower variable input costs and premium prices are available to offset lower yields, organic farmers can often obtain higher gross margins than conventional farmers. This is less likely with livestock. Looking at the gross margin for each enterprise separately can, however, be misleading. High gross margins for cereals and vegetables can be achieved only occasionally as part of a balanced rotation involving livestock and leguminous leys, and are offset by these other enterprises. Conversely, reduced gross margins for livestock may be compensated for by higher gross margins for crops, so that it is not necessarily appropriate to look at beef or milk production just in terms of the premium required to achieve comparability with conventional systems.

In general more labour is needed on organic farms than on conventional ones, although this varies considerably with different enterprises. Much of the labour requirement depends on the level of mechanisation of individual farms.

- Research in Germany, for example, suggests that labour needed for cereal and dairy production differs little between conventional and organic systems; root crops produced organically require more labour; for potatoes, it is estimated that hand weeding demands around 100 more hours per hectare (Braun 1990).
- As with conventional farms, on organic farms there is a clear relationship between labour requirement and size of farm (see table 4.15) (Böckenhoff et al. 1985).
- Small farms often concentrate on high value crops such as vegetables, which demand a much more intensive use of labour. This pattern of higher relative use of labour on small organic farms was borne out by a survey of organic farms in Germany (Lösch and Meimberg 1986).
- In addition, organic farmers are more likely to be involved in

processing and marketing their produce than their conventional counterparts, which results in a higher labour requirement. Around 86% of the organic farms in former West Germany market their produce directly (Braun 1990). Indeed, organic viticulture in Germany secures the equivalent farm income to conventional wine production only when the wine can be sold directly to the customer, as in this way the extra labour costs for hand picking the grapes can be recovered (Dabbert and Oberhofer 1990).

The other point at which need for labour may increase significantly is when a specialised arable or livestock unit converts to mixed farming. As specialisation decreases, the associated economies of scale are lost. But on the other hand, there may also be gains, because on highly specialised farms, particularly arable ones, full-time labour is under-employed for large parts of the year. A switch to a number of different enterprises may therefore allow better use of seasonal labour and reduce costs per unit value of production. Furthermore, organic systems that are less reliant on purchased inputs may contribute more to local economic activity than high input systems (Lampkin 1990).

Losing the "benefits" of specialisation also applies to other fixed cost items, such as machinery servicing and depreciation, and to some extent to the servicing of capital loans. Less working capital, however, is likely to be needed because of the reduction in use of inputs such as fertilisers and pesticides. Other fixed cost items are unlikely to differ between the systems (Lampkin 1990). A Swiss study found that machinery costs were lower on organic farms, but this is contradicted by studies in Germany (Böckenhoff et al. 1986). In general, unless there are dramatic changes to the overall mix of enterprises, fixed costs are not likely to change significantly in moving to an organic system.

Although it is difficult to make meaningful generalisations, there are certainly regions and types of farm for which the net incomes of organic and conventional management systems are similar.

Economics of Alternative Agriculture

By USDA

Economic Evaluation of Alternative Farming Systems

Interest in alternative farming systems is often motivated by a desire to reduce health and environmental hazards and a commitment to natural resource stewardship. But the most important criterion for many farmers considering a change in farming practices is the likely economic outcome.

Wide adoption of alternative farming methods requires that they be at least as profitable as conventional methods or have significant nonmonetary advantages, such as preservation of rapidly deteriorating soil or water resources. Economic performance can be improved in several ways:

Several economic analyses of alternative farming systems were conducted in the 1970s. A review found most of these studies were methodologically flawed, however, and used prices, technologies, and policies that are of limited relevance today (Lockeretz et al., 1984). In particular, energy and land values have fallen, real interest rates have risen, inflation has slowed, cash market commodity prices have generally declined beginning in 1982, and a wide range of government policies have exerted greater influence on farmer decision making. These factors are dynamic and constantly influence agricultural producers and policies.

Nonetheless, a growing body of contemporary data supports the economic viability of alternative farming practices and systems. The committee reviewed and interpreted available literature on the economics of alternative methods and systems, focusing on the general areas of pest control, diversification, nutrient sources, and the effect of government and market price structures on the adoption of alternative practices. Economic findings from the case study farms are presented in this chapter.

Economic Assessments of Alternative Methods

Understanding the overall economic implications of alternative farming systems requires research at several levels, including individual components of crop and livestock enterprises, whole-farm studies, and national and international analyses.

Traditionally, most evaluations of the economic impact of adopting alternative farming practices have focused principally on the cost

and returns of adopting a specific farming method. For example, many studies at the farm level have estimated the economic benefits of integrated pest management (IPM), crop rotations, and manure management options. Such studies generally assume no other changes in the farm operation, input or output, or prices. These studies fall into a broader literature on farm management that employs partial budget analysis techniques.

Fewer studies have considered the impact of alternative farming systems on the economic performance of the whole farm. At the aggregate level, the committee could identify no useful studies of the potential effects of widespread adoption of alternative agricultural systems.

Most aggregate studies are flawed in their methods and assumptions regarding the effectiveness of alternative systems and the impact of commodity policy on farm management. The common approach has been to compare conventional farming practices with the economic performance of a similar farm, assuming total withdrawal of certain categories of farm inputs. These studies usually assume or project substantial reductions in per acre yields in many crops and then project the effect of these reductions in the context of strong export demand and limited commodity supplies. These assumptions and conditions often result in projected food production shortfalls that do not accurately reflect the constant change of markets or the production capabilities of many available alternative systems. The committee could identify no aggregate studies that compare the costs and benefits of conventional agriculture with successful alternative systems. Such analyses are needed but will be complex, involving a wide range of factors.

Economic Studies of Farming Practices

Economic analyses of single enterprises or their components usually employ partial budgeting techniques that estimate the change in production costs, profits, and risks accompanying a specific change in farming practice (Boehlje and Eidman, 1984). Results are often expressed as a change in the net return over cash production costs per acre or per unit of output. Methodologically, partial budget studies focus on short-term net returns, including labor, and generally do not take into account off-farm impact or long-term changes in the productivity of the natural resource base. They also assume no change in farm size, enterprise combinations, prices of commodities or inputs, or other variables.

Despite these limitations, this method is practical and easy to understand. Partial budget study findings can be augmented by drawing on additional analyses from specialists in biology, ecology,

and physical science. In recent years, biological, physical, and social scientists have made much progress in their collaborative research efforts in developing new methodologies for estimating the economic consequences of farming systems and practices.

Partial budgeting is reported to be the most widely used method of estimating changes in income of an individual farm as a result of adopting IPM (Allen et al., 1987; Osteen et al, 1981). The landmark research on the economics of crop rotations by Heady (1948) and Heady and Jensen (1951) was based essentially on the partial budgeting approach, because the only aspect of the farm operation assumed to vary was the crop rotation. Contemporary research that includes a greater consideration of biological and economic factors is presented later in this discussion (Goldstein and Young, 1987; Helmers et al., 1986). The review by Allen et al. (1987) of the agricultural, economic, and social effects of IPM is another example of the multidisciplinary approach to partial budgeting analysis.

Whole-Farm Analysis of Alternative Methods

Frequently, a farming method that appears profitable when analyzed at a component level may prove less attractive from the perspective of the whole farm, particularly in relation to other possible practices or combinations of practices.

Analysis at the whole-farm level recognizes that a farmer's decision to adopt one or more farming practices is not made in isolation from the rest of the farm enterprise. Perhaps the most important factor in adopting any management system or combination of crops is the net return to the farm family. The successful commercial farmer must assess the compatibility of proposed alternative practices with other practices already in place, taking into account a farm's physical and biological resources and anticipated changes in crop yields, livestock productivity, production costs, farm programs and policy, and labor and machinery requirements. These and other factors will strongly affect the farm operator's cash flow and the farm's profitability and long-term economic viability.

Whole-farm studies typically use one of two approaches: linear budget (risk programming) or overall farm surveys. Both approaches attempt to examine the effect of different farming practices or production systems at the farm level, taking into account all components of the farming system and operation, such as land-use patterns, pest control practices, and nutrient management.

Microeconomic programming or planning models analyze farm decision making based on particular resource and financial assumptions as well as estimated relationships between management choices

and crop or animal production levels. The usefulness and validity of these models depend on the availability of reliable experimental or empirical data on input and output relationships in specific agricultural systems. When such data are present, whole-farm planning models can analyze the economic consequences of a wide range of alternative production systems. A principal objective of the committee's research recommendations is the development of such a knowledge and information base (see the Executive Summary).

Partial-and whole-farm analyses can take a short-or long-term perspective. For short-term analyses, some resources and technologies are assumed fixed, and management decisions are made among existing alternatives. Long-term studies are more complex and difficult because many more variables are changeable, including technologies and policies. A critical need identified by the committee is expanded multidisciplinary research on long term technological trends and policy changes and how these trends and changes are likely to influence the relative costs and benefits of various farming systems. For example, the committee suspects that biotechnology will greatly increase technological options in support of alternative agricultural systems, and that society's environmental and public health goals will tend to support producers successfully adopting these technologies. The committee cannot go further in quantifying these trends, however, because the necessary knowledge base and analytical framework do not exist.

Farm surveys are based on empirical measures of the performance of agricultural production systems. It is often difficult to draw cause and effect inferences from surveys, however. For example, farm operators' technological choices and management abilities greatly influence profitability. But it is difficult to separate the contribution of technology from that associated with managerial skill. Nonetheless, the performance of agricultural systems as captured in well-designed surveys implicitly reflects the interaction of these factors. Experimental data on alternative agricultural systems are clearly lacking, and relatively few well-designed surveys have been undertaken. The literature is beginning to grow, however, and a number of solid studies have reached conclusions indicating the prospective economic benefits of alternative production systems.

The Transition to Alternatives

Most economic studies of alternative production at the whole-farm level take a static approach, ignoring the year-to-year difficulties associated with the transition from one system to another. Moreover, the assumptions used generally ignore uncertainty stemming from the weather, crop yields, management skills, prices of

inputs and products, government policies, and other variables. As a result, these studies must be interpreted cautiously.

Several whole-farm studies have examined the financial impact of changing from conventional to alternative farming practices (Hall, 1977; Osteen et al., 1981; Reichelderfer and Bender, 1979). These studies recognize that a farm's economic performance can change significantly during a multiyear evolution from conventional to alternative practices (Dabbert and Madden, 1986).

Many factors can influence the economic performance of farms during the transition to alternative practices. The use of certain kinds of pesticides and fertilizers may have disrupted natural predators and other biota. Reestablishing these populations and the balance among them can occur quickly or require several years (Koepf et al., 1976; U.S. Department of Agriculture, 1980). Although crop rotations will generally increase yields, decrease pesticide costs, and, in the case of legumes, decrease fertilizer costs, the full benefits of crop rotations may take several years to materialize. Depending on the prices of farm commodities and inputs, adoption of a rotation sometimes reduces net farm income, particularly during the initial years of a transition (Dabbert and Madden, 1986). For example, including a forage legume in a rotation may not sufficiently decrease production costs and increase the yields of cash grain crops to compensate for the reductions in their acreage—especially when cash grain prices are supported far above market levels (Duffy, 1987; Goldstein and Young, 1987). Farmers may also need a few years of experience to acquire the additional knowledge and management skills necessary for more diversified operations. The economic impact of a farmer's decision to change from conventional to alternative farming methods on all or part of a farm operation will vary depending on factors such as climate, soil type, crops and livestock produced, cropping history of the farm, the farmer's skills, and many other considerations.

Because of these factors, most farmers adopt alternatives gradually. Although the transition may be difficult, successful alternative systems tend to reduce variability of net returns (Helmers et al., 1986). The consistency of yield and return to the farm family is a potential benefit of alternative agriculture that deserves further study.

Summary

Research has begun to demonstrate the economic benefits of alternative farming systems and how current policies impose incentives and disincentives for the selection of various types of farming systems.

The committee's case studies provide examples of several profitable alternative operations. Additionally, several farm surveys provide general information about the overall financial performance of farmers using low-input methods, such as those who practice organic farming. But many questions remain unanswered. Farm surveys do not provide conclusive evidence regarding the advantages and disadvantages of different farming methods because many factors are randomized or not constant. Somewhat more systematic data are available regarding the economic performance of IPM programs. IPM has been highly successful in many instances. Farmers who use IPM usually reduce the amount of pesticides applied and increase their net returns compared with farmers who apply pesticides on a regular schedule.

Diversification strategies such as crop rotations can decrease input costs and increase crop yields. Experimental results must be interpreted with caution, however, when used to project the results of widespread adoption. Nonetheless, rotations have the potential to simultaneously increase farm income and reduce farm program expenses. Forage legumes in the crop rotation have the added advantage of supplying nitrogen. But when cash grain prices are supported far above the market level, many farmers would reduce their net farm incomes if they shifted from growing only price-supported crops, such as corn and soybeans, to legume-based rotations—unless commodity program rules are reformed.

Livestock are an essential component of some diversified alternative cropping systems. Many alternative farming systems, however, do not depend on livestock. Examples include perennial crop systems such as orchards and vineyards, and vegetable and other annual crop farms that use legumes as green manure crops or import organic residues from off the farm. Diversification can reduce risks and variability of net returns to farm families. For these reasons, it should be studied in more detail.

Very little is known about the aggregate impacts of possible widespread adoption of alternative farming methods. Future economic research on alternative farming methods should examine social and aggregate costs and benefits. This research should be integrated with that of other agricultural disciplines, the Extension Service, and the private sector to apply the results at the farm level.

Biodiversity-Based Productivity

By Vandana Shiva

The False Productivity of the Dominant Paradigm

The dominant productivity calculus neither measures the environmental benefits or costs of different agricultural practices, nor the full economic benefits and costs that are related to different agricultural systems. It only measures partial outputs which have a commercial value for dominant interests and financial incomes derived from them. It does not fully reflect additional financial costs when agricultural practices shift from internal input to external input agriculture, and from diversity based systems to monocultures.

Cropping systems include a symbolic relationship between soil, water, farm animals and plants. Traditional agriculture links them together in sustainable ways, where each is dependent on the other and the relationship between them in is thus strengthened. Green Revolution agriculture replaces this integration at the level of the farm with the integration of inputs such as seeds and chemicals. Not merely does the seed/chemical package break traditional farming interlinkages, it also sets up its own interactions with soils and water systems. These new interactions are, however, not taken into account in the assessment of yields.

Modern plant breeding concepts like HYVs reduce farming systems to individual crops and parts of crops.

Crop components of one system are then measured with crop components of one another. Since the Green Revolution strategy is aimed at increasing the output of a single component of a farm, at the cost of decreasing other components and increasing external inputs, such a partial comparison is, by definition, biased to make the new varieties "high yielding" even when, at the systems level, they may not be.

Traditional farming systems are based on mixed and rotational cropping systems, of cereals, pulses, oilseeds with diverse varieties of each crop, while the Green Revolution package is based on genetically uniform monocultures. No realistic assessments are ever made of the yield of the diverse crop outputs in the mixed and rotational systems. Usually the yield of a single crop like wheat or maize is singled out and compared to yields of new varieties.

Even if the yields of all the crops were included, it is difficult to convert a measure of pulse into an equivalent measure of wheat, for example, because in the diet and in the ecosystem, they have

distinctive functions. The protein value of pulses and the calorie value of cereals are both essential for a balanced diet, but in different ways and one cannot replace the other.

Similarly, the nitrogen fixing capacity of pulses is an invisible ecological contribution to the yield of associated cereals.

The complex and diverse cropping systems which are based on indigenous varieties are therefore not easy to compare to the simplified monocultures of HYV seeds. Such a comparison has to involve entire systems and cannot be reduced to a comparison of a fragment of the farm system. In traditional farming systems, production has also involved maintaining the conditions of productivity.

The measurement of yields and productivity in the Green Revolution paradigm is divorced from seeing how the processes of increasing output affect the processes that sustain the condition for agricultural production. While these reductionist categories of yield and productivity allow a higher measurement of yields, they exclude the measurement of the ecological destruction that affects future yields. They also exclude the perception of how the two systems differ dramatically in terms of inputs.

The indigenous cropping systems are based only on internal organic inputs. Seeds come from the farm, soil fertility comes from the farm and pest control is built into the crop mixtures. In the Green Revolution package, yields and intimately tied to purchased inputs of seeds, chemical fertilizers, pesticides, and petroleum and to intensive and accurate irrigation. High yields are not intrinsic to the seeds, but are a function of the availability of required inputs, which in turn have ecologically destructive impacts.

When the external costs of additional inputs are taken into account, agricultural "improvement" is often a regression, not an improvement, either in terms of productivity or income. The Karnataka farmers' experience with multinational hybrid seeds of sorghum and sunflower in 1993 show the higher costs of production and hence the lowering of farmers' incomes as compared to the cultivation of native varieties.

A system of productivity assessment is therefore needed which reflects the full costs and full benefits of agricultural systems, and measures the maintenance, growth, and destruction in the three economies of nature, people and the market not just the growth in the market economy from the perspective of dominant commercial interests. The reflection of the production of the full range of goods and services at the systems levels requires that the 'productivity' and 'yield' be based on a calculus of diversity, and not on a reductionist category of a part of the agricultural system.

Towards a Biodiversity-Based Productivity Framework

According to the dominant paradigm of production, diversity goes against productivity, which creates an imperative for uniformity and monocultures. This has generated the paradoxical situation in which modern plant improvement has been based on the destruction of the biodiversity which it uses as raw material. The irony of plant and animal breeding is that it destroys the very building blocks on which the technology depends. Forestry development schemes introduce monocultures of industrial species such as eucalyptus, and push into extinction the diversity of local species which fulfils local needs. Agricultural modernisation schemes introduce new and uniform crops into farmers' fields and destroy the diversity of local varieties.

Modernisation of animal husbandry destroys diverse breeds and introduces factory farming. This strategy of basing productivity increase on the destruction of diversity is dangerous and unnecessary. Monocultures are ecologically and socially non-sustainable because they destroy both nature's economy and people's economy.

In agriculture and forestry, in fisheries and animal husbandry, production is being incessantly pushed in the direction of diversity destruction. Production based on uniformity thus becomes the primary threat to biodiversity conservation and to sustainability, both in it's natural resource and it's socio-economic dimensions.

Not till diversity is made the logic of production can diversity be conserved. If production continues to be based on the logic of uniformity and homogenisation, uniformity will continue to displace diversity. "Improvement" from the corporate viewpoint, or from the viewpoint of western agricultural or forestry research, is often a loss for the Third World, especially for the poor in the Third World. There is therefore no inevitability that production should act against diversity. Uniformity as a pattern of production becomes inevitable only in a context of control and profitability.

Plant improvement in agriculture has been based on the "enhancement" of the yield of desired product at the expense of unwanted plant parts. The "desired" product is however not the same for agribusiness and Third World peasants. Which parts of a farming system will be treated as "unwanted" depends on what class and what gender one belongs to. What is unwanted for agribusiness may be wanted by the poor, and by squeezing out those aspects of biodiversity, agriculture "development" fosters poverty and ecological decline.

Overall productivity and sustainability is much higher in mixed systems of farming and forestry which produce diverse outputs.

Productivity of monocultures is low in the context of diverse

outputs and needs. It is high only in the restricted context of output of "part of a par" of the forest and farm biomass. E.g "High yield" plantations pick one tree species among thousands, for yields of one part of the tree (e.g. pulpwood).

"High yield" green revolution cropping patterns pick one crop among hundreds e.g. wheat for yields of one part of the wheat plant (only grain).

These high partical yields do not translate into high total (including diverse) yields. Productivity is therefore different depending on whether it is measured in a framework of diversity or uniformity.

A recent article in *Scientific American* has developed this approach further and has shown how the economic calculations of agricultural productivity of the dominant paradigm distort the real measure of productivity by leaving out the benefits of internal inputs derived from biodiversity as well as the additional financial and ecological costs generated by purchase of external inputs to substitute for internal inputs in monoculture systems.

Given the rapid changes in agriculture taking place because of liberalisation, there is an urgent need to monitor the ecological costs of globalisation of agriculture using a biodiversity based productivity framework to reflect the health of nature's economy and people's economy. We have developed such a framework over the past decade.

The framework:

a) provides documentation of the biodiversity status of a farm including crop, tree and animal biodiversity.

b) indicates the contribution of biodiversity to provisioning of internal inputs and to the building and maintenance of "nature's economy" through the conservation of soil, water and biodiversity.

c) indicates the contribution of biodiversity to the self-provisioning of food needs by agricultural families and communities and to the building and maintenance of "people's economy".

d) reflects the market economy of the farm in terms of incomes from sale of agricultural produce, and of additional costs for purchase of external inputs and food items, when benefits from biodiversity are foregone.

The biodiversity-based productivity framework has been kept simple to allow participatory research by farmers in evaluating agricultural change on the basis of the needs of the land and the needs of farming communities, and to allow for comparisons across diverse ecosystems and farming systems. It can be adapted to reflect the complexity of the socio-economic context of farming. We welcome you to join us in developing this biodiversity-based productivity to realistically and honestly reflect the status of nature's economy and people's economy, which are the economies on which life depends

Examining the Productivity of Old and New

By Korah Mathen

In the name of "development ", "growth", "progress", "productivity", "efficiency", etc., science is being progressively used to replace and control nature and its processes, by artificial intervention which ensures exclusive profits, for a few, at the expense of the rest. For example, it is now possible through bio-technology to create hybrid crop seeds which incorporate pollen inhibiting genes, which promise a 20% increase in yield. This effectively ensures that any sort of natural pollination (hitherto, done freely by the wind, birds, bees etc.) cannot take place, making farmers everywhere totally and completely depend on the seed companies. What a marvellous route for sustained exploitation! It is as if no other ecologically saner alternative to obtain such an yield increase is possible. Already many other natural processes have been taken over (e.g. seeds germination, dispersal, pest control, soil fertility, etc.) at a cost which we are yet to adequately estimate, in terms of the social, ecological and traditional knowledge base erosion.

We should not, therefore, in our state of ignorance, categorise, label and condemn what we cannot fully explain as "unscientific", "primitive", "inefficient", "wasteful", "unviable", etc. For example, what may look like disorder, may be in reality, order of a highly complex and sophisticated level, superimposed in a manner that makes it look chaotic (e.g. climate cycles). Over-simplification in such matters, is a dangerous superstition.

We believe, or have been led to believe, that proper "scientific research" is a recent phenomena, in human history—and, that everything preceding was largely, a matter of accidental discovery. Also, that it is the exclusive monopoly and preserve of our more qualified members. Yet, nothing can be further removed from the real truth. The history of the centuries old, man-nature interaction, in ancient India, had resulted in the stunning array of genetic diversity in crops, trees, animals, etc., that we see today. This tremendous genetic diversity, that thus came into being, was not a random, accidental, chance process. It was the product of a highly developed observational science, tempered by intelligence and wisdom, refined over time. Countless innovations, interactions and ideas, have been internalised into this process. Above all, it was a continuing and dynamic process, that pooled in the efforts and participation of almost every individual—a truly decentralised process.

For example, Winin Pereira writes:

"Warlis use a wild, fast-growing nitrogen-fixing plant, Sesbania bispinosa, as a green manure for paddy, by sowing it in paddy fields

at the first rain and ploughing it in within three weeks, just before transplantation. It provides sufficient nitrogen for the crop. A similar method was later discovered by 'highly qualified scientists' at the vast establishment of the International Rice Research Institute (IRRI) in the Philippines. They used an African species, Sesbania rostrata, which required irrigation for six months before being ploughed in.

"Since 1987, Warli Adivasis have been catching fish by stupefying them with the seeds of dandavan (Acacia auriculiformis). The Australian tree was first introduced into the Warli area around 1985. It takes about two years to flower and fruit, so that Adivasis research has been carried out very quickly, indeed.

"A paper on the effects of extracts of this plant on fish was published in 'Environment & Ecology' in 1988. The research required submission of project reports and budget, a well-equipped laboratory, two species of 'experimental' fish confined to aquaria, two 'qualified' scientists who carried out the research, their guides, supporting staff from clerks to cleaners and accountants to administrators, large salaries, and a lot of time spent by all concerned. The Warli research requires no submission of reports and budgets, no elaborate establishment, no requisitions for apparatus and consumables, and was tested on the fish that needed to be caught, in their natural environment. Warlis already use several plants for this purpose, so that research may have been done purely out of scientific curiosity or because those plants have disappeared with their forests, replaced with monocultures of dandavan.

"The new knowledge has already diffused so widely that it has not been possible to trace who exactly did the research. The need for recognition did not arise since what they did was nothing extraordinary—it was what all of them normally do. The researchers felt no need to write a paper, submit it for publication and wait for people to read, cite and use it. When appropriate, traditional technologies spread without 'extension experts' and 'modern' methods of communication; such research will not be cited in any 'earned' journal but its knowledge has already benefitted many. And those who did it, exercised their creativity and thus enhanced their self-worth. Above all, it remains common intellectual property."

The following analysis, albeit brief, is not intended to support or encourage the current globalisation\homogenisation of societies. In fact, quite the opposite. The process, when undertaken in detail, will only show up the irrationality of most of the current trends, practices and developments. Sustainability cannot happen with the promotion of electric yogurt curd makers, in a country like India. Nor can it happen just because we've changed over to organic inputs in agriculture. If we continue to demand fresh oranges, or mangoes, for

example, round the year no matter whether you grow it chemically, or organically, it does not become sustainable.

There is an endless variety of available evidence, which clearly establishes the healthy and flourishing state of our agriculture in the pre-British period. British observes of the 18th century onwards, who attempted to survey our agriculture practices, were not always in a position to appreciate the intricacies and sophistication that went into our traditional systems of agriculture. Nonetheless, it was documented. Several indigenous practices commonly prevalent in India agriculture were then unknown to the western world and emerged as so-called agriculture advances, later on in the west. Whether it be in agriculture practices, yields, systems of irrigation, restoring soil fertility, related animal husbandry practices, agriculture implements, post-harvest storage of grains or even payment of agriculture labour, we were in real terms far better off than our British and European counterparts. Yields in certain cases, were equivalent or better than comparable yields with modern chemical farming (PPST data). A number of documents testify to this—right from the 18th and 19th centuries. Such a system obviously did not suit the designs of our colonial rulers. Starting with the subversion of the Indian education system, the village, administrative and revenue system, the Brandeis Forest Act, neglect of our earlier well maintained irrigation systems, extensive exploitation of natural resources, over time, brought Indian agriculture down to its knees. It is this enfeebled Indian agriculture system, which had to bear the brunt and onslaught of modernisation.

This situation, I am sure, would be true of many other parts of the world where any similar documentation/evidence exists. Some recent data like the Peruvian ridge farming system, dating back 4,000 years, cited in the book, "Lost Crops of Incas".

However it must be re-stated that natural/organic farming had its basis in indigenous genetic varieties, which had stood the test of time, in terms of being adapted to the local environment, pest and disease patterns therein. Amongst them were also very high yielders, as has been convincingly shown by Dr Richharia's work in rice (Gudur Sela at 9.7 tons/ha.) or, the evidence thrown up by the PPST team, from the archival British records (upto 13/ha. for rice with an average or around 8 tons/ha. spread over 130 villages).

A Matter of Comparison

Next comes, grappling with the issue, of trying to inject and incorporate, a truly "scientific" basis, for evolving yardsticks of comparison between the modern and the traditional. True scientific rigour is

characterised by a proper balance between the quantitative element and the qualitative one. This is easier said than done in actual practice. Let me explain.

Firstly, the moment we look at modern chemical-based/factory-oriented farming we are examining only the direct agricultural operations, independent of everything else around. As against that, organic/natural farming can never be viewed in isolation of the larger system which sustains it, and to which it contributes. A comparison between the two, ends up in a comparison between a component and a system, in which the component is just a part.

Secondly, we are looking at a fairly structured, well defined and more or less standardised set of practices which fall under the umbrella of modern agriculture and a limited number of cropping alternatives, in one case. On the other side, we have to take into account the tremendous diversity of creative responses of farmer-researchers, over a wide range of crops and crop varieties. Aggregating this diversity in order to come to some convenient basis of comparison, is to deny its role and importance, in the entire framework of things.

Thirdly, the overall balance sheet mentality which makes us, focus on short term yearly figures of output, profit, etc. combined with the selective externalising of costs which we would rather not like to take into account or bear, is designed specifically to advance the cause of modern agriculture. A high-mean high-variance yield strategy, is the outcome—whereas the strategy in organic/natural farming is to have a low variance, with maximisation of mean yield. In other words, the optimisation between long term survival and sustainability, keeping in mind current needs is pitted against current wants and short term (yearly) profit maximisation. How do we compare the two? Where do we start? In a proper scientific study the base conditions have to be more or less equal. Here the very preconditions of success in a natural/organic system are totally different from that of chemical-based farming. Even if we attempt to start off with almost the same type of fertile soil, rich in humus and organic matter, teeming with earthworms and other soil organisms, well aerated and with good moisture retention capacities, etc.— this gets immediately altered with the introduction of chemical fertilizers, pesticides, etc. Therefore, even if we start off with almost comparable base conditions, they do not remain comparable, over time. We have perforce to start off with differing base conditions, because chemical agriculture works best in conditions dissimilar to those demanded by natural/organic farming. Even locational and previous use patterns have a bearing on the matter, in case of organic/natural farming.

The soil is the womb—the receptacle which carries the seed, allows it to germinate, nourishes it, etc. The seed carries in it the ge-

netic blueprint of its species, which it can express, given the proper environment to do so—i.e. soil, water, etc. In human terms, it has long been established that the health of the mother is the single most important determinant in the health of the offspring. In plant life, we have deliberately chosen to do otherwise i.e., concentrate on the seed—because it is amenable to centralised, controlled manipulation, for the profit of a few. Soil would have been impossible to control in this centralised manner, for profit-making. Hence the introduction of what was deliberately named as HYVs, in order to mislead people—they are HRVs (high response varieties), in the true sense.

Local improvements among indigenous varieties have always remained a farmer-based ongoing research activity. Once again, what is best for natural/organic farming, will not work in the other system, which needs modern HRVs, programmed to respond to an orchestrated sequence of external inputs. We have perforce to start with different seed varieties, for a proper comparison of the potential of the two systems, which brings me into the mean-variance equations—or, the error friendliness of the two systems. HRVs are designed to respond only to well programmed and managed input systems. Any variations on this, due to natural, human or other causes, will have serious adverse impact in the response of these varieties i.e., in the final yield. Their sensitivity to this is very high, ending up in a high mean-high variance-yield situation. Combined with a high risk-high dependence equation. Again yields, which show dramatic increases in the initial years, taper off, as per the law of diminishing returns. It ends up in a vicious cycle, where one continues to pump in more and more inputs, with the prospect of getting commensurate returns growing dimmer every year.

This is sharp contrast to the natural/organic farming scenario where yields are likely to be initially lower, but stabilise with a low variance factor. The ability to withstand various agri-climatic and other stresses and strains makes these indigenous inputs more reliable, over time. How then, does one have a proper comparison built up, over a longer time frame, to really study the respective strengths and weakness of the two systems?

Coming to the yield issue once again, we run into problems. Modern chemical agriculture would imply large tracts of monoculture cropping, mostly of a single variety in order to maximise output. Natural/organic farming would perforce mean a mix of crops and even multiple varieties of same crop, in any given area. Obviously the outputs are different. How does one compare say 7 tons of rice/ha in chemical agriculture versus 3 tons of rice plus 2 tons of other items like fish, different vegetables, coconuts. Total food supply makes more sense—but, does not lend itself to any sensible way of

quantification. How does one measure this—calorific value of the food—available carbohydrates, proteins, or what have you—total digestible or assimilable nutrients—which again, depends on whether it is raw/cooked/sprouted/fermented, etc.— and, the style of cooking, apart from the specific genetic make-up of the population consuming such food.

Total bio-mass output (as used by G. Stanhill in his paper "The comparative productivity of organic agriculture") may be a better indicator, but still falls short of expectations, when tree-crops are included. Also, the problem of what fraction of this bio-mass is available for man, how much for cattle etc. will create additional complications. Even so, his conclusions show that the ratio of organic/natural farming yields to modern agricultural yields, were normally distributed with a mean of 0.9 and a mode between 0.8 and 0.9. Straight yield comparisons undertaken in the US (refer ILEIA Newsletter—October 1990—"Alternative Farming—Lower Yields a Myth" by Jack Fenwick and Pat Mielnick) indicate that yields through alternate agriculture are not necessarily lower than those obtained by modern chemical methods. Closer home, the experience of Shri Narayan Reddy (probably, the most frequently documented case) shows that, translated into economic terms, his non-chemicalised farming has yielded better returns. There are many more less publicised examples too.

We have so far only taken stock of the direct input-output equations. The next is the indirect, but easily observable aspects, which never get quantified into our costs framework. In other words, these costs are always externalised. Impact on soil structure, fertility etc., biotic activity in soil, erosion of genetic diversity, changes in nutrient values, health impacts through pesticide residues, etc. remain largely unexplored in terms of assessment, in monetary terms.

Other even more difficult issues remain untouched i.e. the not so tangible areas. Changes in bio-mass usage patterns, and its consequent impact on land and water use pattern; pressures on land between man, animal, fuel, etc. come into this category. Also the implications of the dependencies created, at the input stage, the process stage and the output marketing stages also have not been taken into account. The quality of risks involved, the error friendliness of the systems, specially in a factory feedstock oriented agriculture, has also not been touched upon.

Economic analysis is even more of a problem. Quantification of intangibles, or even, tangibles which have larger time frame cannot find a proper place. For example, by avoiding toxic chemicals—what is the inputted value of illness prevention for human, animal, aquatic and the overall environment, preservation of the soil balance, reduced soil erosion, better water and nutrient retention, contribution towards

ensuring genetic variability and diversity, etc. Implications of the kind of irrigation systems required to keep the systems operational e.g., big dams versus surface rain water harvesting. Also, relationships, between different types of vegetational mix, soil conservation status, types of farm implements used. Implications at storage level, also need to be considered. In addition, other socio-political dimensions, like what happens to common property resources like water, the promotion of community interdependence versus implications of increasing external dependence incidence of under and unemployment, etc., also figure. The greatest loss would be the genocide of the collective, accumulated knowledge system of the people, which had sustained society till date. How does one value it? In all, a pretty complicated mess.

Having said all this, does one throw up one's hands in sheer desperation? No, there is still a way out—imperfect, as it may be. This I believe, is through "resource use efficiency" analysis. Put briefly, I am suggesting looking at different systems, through an input-output analysis, keeping in mind the qualitative aspects of the inputs, and its implications. In other words, the inputs involved per unit of output, inclusive of all the backward linkages, including extraction, processing, packaging, distribution and marketing till the final input stage. Since modern systems are promoted on the myth of input "efficiency", such an approach can expose the hollowness of the claims made. Arguments against this would be about the quantum of the total production i.e., the demand, vis-a-vis population pressures, etc. That would raise issues related to the pattern of use of land-related resources, diet systems, food processing, agro-industry nexus, etc. for which some data is available: e.g. a given acreage can feed twenty times as many people eating a pure vegetarian diet-style as it could, people eating the standard American style diet.

Emerging Alternatives

Perhaps the most important misconception about the diverse farmer-evolved farming systems is the claim that they tend to produce less than monocultures. They might produce quantitatively less of one and the same crop, but generally the combinations yield far more. Henk Hobbelink's book, "Biotechnology and the Future of World Agriculture" gives the following data:

"Researchers in Mexico established that 1.73 hectares of land would be needed to obtain the same amount of food as one hectare of a mixture of maize, beans and squash. Bolivian farmers intercrop beans, potatoes and lupins and in virtually all cases obtain higher yields compared to monocropping. Additionally, viral and fungal diseases are significantly lower in the mixed cultures and the

intercropped potatoes store better. Graph 9.1 (not shown here) shows the extent of one year's production on a small poly-cultured plot of about 400 square meters in the Philippines in which 12 different crops produce over two tonnes of fruits, vegetables, spices and cash crops—a yield of about 50,000 kilograms per hectare! No hybrid seeds, irrigation or mechanical farm implements, and only a small amount of chicken manure were used.

Often ignored in official production statistics are the multiple uses that crops can have. While a typical local vegetable can be grown mainly for its leaves, its roots might have medicinal properties. Shrubs and trees, apart from producing food, can provide foodstuff for animals and timber for building and fuel. Perhaps the prime example of a multiple use crop is the coconut, "the tree of a hundred uses". While production statistics mainly focus on the industrial products such as oil, local farmers use the crops for a whole range of purposes. Coconut flesh and milk are consumed fresh, the copra is used to produce oil for local use, the trunk is used as a construction material, the palm as thatch or to make brooms and baskets, the shell as fuel and the sap of the tree is the basis for local wine production.

These are not isolated examples. The creative ingenuity of native farmers all across the world is spawning a rich array of diverse strategies and alternatives, each adapted and fine-tuned to their specific micro-environmental niche. They come across under varying labels—natural farming, organic farming, regenerative farming, eco-farming, bio-dynamic farming, vermiculture, permaculture, ridge farming, sloping lands agriculture, etc. This rich variety is indicative of the degree and extent of creative responses that local farmers, left to themselves, are capable of. No one method is sacrosanct nor applicable across the board, in all situations and conditions. Hence the need for diversity, even in approaches. If we wish to wear the label of a "scientist", then we must do justice to it, by understanding and identifying the basic generic scientificity of such practices. This will help restore self-confidence badly needed to restore ecological sanity.

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The Organic Farming Reader

The *Organic Farming Reader* is one of the companion volumes of the *Organic Farming Source Book,* also published by the Other India Press. The *Reader* was explicitly designed to function as a text for the Winter Schools on Organic Farming organised by ARISE.

The *Reader* has five sections which deal with different aspects of organic farming:

• The philosophy and ethics of organic farming. This section contains extracts from the writings of many of the pioneers of organic farming from all over the globe.

• The regeneration of the soil. This section contains stimulating and fascinating new information on the theory and practice of organic farming, particularly on how plants function and their relationship with the soil.

• The crisis of biodiversity. This section discusses the principal challenges facing biodiversity conservation today. It shows how the great erosion of traditional seeds poses to the food security of people in the non-industrialised world.

Problems between human beings and insects and the warfare between them. This section provides important indigenous perspectives on pest control taken from Ayurveda.

• The economics of organic farming. The section includes important analyses comparing the productivities associated with organic and conventional farming systems.

The *Reader* has now been brought out in book form for the benefit of those who may not be able to participate in the Winter Schools being organised by ARISE. Farmers, policy makers, students of agriculture, environment groups and those involved in rural development will find in it not only great insights into sustainable agriculture, but much practical wisdom as well.

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